MONETARY POLICY IN EMERGING MARKET ECONOMIES

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This dissertation studies monetary policy in emerging market economies and addresses three important questions from both a normative and positive perspective.

Chapter 1 studies how central banks should react when capital flows are volatile. The analytical framework is a Markov-switching dynamic stochastic general equilibrium model that features time-varying external volatility. Computational results suggest that central banks can improve welfare and maintain macroeconomic stability if they allow the response coefficients in the interest rate rule to vary according to the external volatility regime. The optimal simple rule suggests that central banks should target inflation when external volatility is low and stabilize exchange rates when it is high, which is akin to the "leaning against the wind" approach adopted by some emerging market central banks.

Chapter 2 studies the optimal inflation target for an emerging market central bank. Existing research on advanced economies shows that targeting core inflation enables monetary policy to maximize welfare. This result is examined in the context of emerging market economies, where a large proportion of households are credit constrained and the share of food expenditures in total consumption expenditures is high. Results obtained using an open economy model with incomplete financial markets indicate that headline inflation targeting improves welfare outcomes. The optimal price index includes a positive weight on food prices but

assigns zero weight to import prices.

Chapter 3 studies the inter-sectoral distributional effects of monetary policy in emerging market economies. Emerging market economies with fast-growing tradable sectors often face appreciation pressure, and they tend to use monetary policy to postpone currency appreciation and maintain export competitiveness. A two-sector, heterogeneous-agent model with incomplete financial markets is developed to study the inter-sectoral distributional effects of such policy choices. Relative to inflation targeting, exchange rate management can temporarily benefit households in the tradable sector in high-growth periods, but these households are worse off under the welfare criterion due to higher future consumption volatility. Capital controls and fixed exchange rate regimes amplify those distributional effects.

BIOGRAPHICAL SKETCH

Boyang Zhang started working toward his doctoral degree in economics at Cornell University under the tutelage of Professor Eswar Prasad in 2011. His research interests cover macro and monetary economics, international finance, and emerging market economies. His research has been presented at many academic conferences and policy meetings and has appeared in the *Journal of Monetary Economics* and the *Oxford Companion to the Economics of China*. He was chosen as the only PhD candidate in economics from a U.S. university to receive the prestigious Chinese Government Award for Outstanding Students Abroad in 2016.

Prior to studying at Cornell University, he received his bachelor's degree in mathematics and economics from Peking University, where he wrote his undergraduate thesis under the supervision of Professor Huang Yiping and won the China Economic Research Scholarship (the highest honor for students with economics as a double major).

In addition to his academic pursuits, he has worked at the National Bureau of Economic Research, the International Monetary Fund, and the Chief Economist Office of the World Bank.

To my beloved wife Yichen Guan and my parents

献给我的妻子官逸尘和我的父母

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Six years ago, through a seminar class I attended as an exchange student at Yale, I became deeply interested in the research of Eswar Prasad, a Cornell professor. As a result, when I decided to pursue my doctorate in economics, I wrote to Professor Prasad and asked whether he could serve as my PhD adviser. Thanks in part to the strong recommendation of my undergraduate thesis adviser Professor Yiping Huang, Professor Prasad gladly accepted me as his student.

Now six years have passed and I simply cannot express how fortunate I am to be his doctoral student. Professor Prasad is a very knowledgeable scholar, a highly helpful adviser, and a truly magnificent role model. The cutting-edge research taught in his inspiring lectures, the equations we worked out together in his office, and the working lunches we had are all great memories that I will never forget.

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Specific acknowledgement for each chapter is given below. For Chapter 1, I am grateful for comments from Changhua Yu, Miaojie Yu, and conference participants at the Royal Economic Society Annual Conference and the Chinese Economist Society Annual Conference.

A different version of Chapter 2 (Anand, Prasad, and Zhang, 2015) was published in the *Journal of Monetary Economics* under the title "What measure of inflation should a developing country central bank target?" I am grateful to my coauthors Rahul Anand and Eswar Prasad, as well as the editor, Ricardo Reis.

A different version of Chapter 3 (Prasad and Zhang, 2015) was previously circulated as an NBER working paper under the title "Distributional effects of monetary policy in emerging market economies." I am grateful for comments provided by participants at the Royal Economic Society Annual Conference, IMF-UK DFID Conference on "Macroeconomic Challenges Facing Low-Income Countries," CEP-Federal Reserve Bank of Atlanta Workshop on Monetary Policy and Inequality, the China Meeting of the Econometric Society, and the Midwest Economic Theory and Trade Conference. Edward Buffie and other colleagues provided helpful comments and suggestions.

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CHAPTER 1

CENTRAL BANK POLICY RESPONSES TO VOLATILE CAPITAL FLOWS

1.1 Introduction

Central banks in emerging markets have followed two major trends in policy reform over the past few decades: liberalizing their capital accounts and adopting a flexible exchange-rate regime. While emerging market economies continue to impose more rigorous capital account regulations compared with advanced economies, capital account openness has increased substantially.[1] In the meantime, cross-border capital flows have risen dramatically (Lane and Milesi-Ferretti, 2007) and the fixed exchange-rate regime was abandoned in favor of a flexible exchange-rate regime. Instead of pegging their currencies to the dollar, many emerging market central banks are now adopting inflation targeting as the foundation of their monetary policies (Roger, 2010).

However, having open capital accounts also makes emerging market economies more vulnerable to large foreign interest rate shocks, often resulting in volatile capital flows and considerable exchange-rate fluctuations. I construct the real foreign interest rate processes for eight emerging market economies and find strong evidence of time-varying volatility. The foreign interest rate process is characterized by two regimes of shock volatility: the high-volatility regime and the

[1] See Chinn and Ito (2006) for more information about the capital account openness index they construct, which is available at: `http://web.pdx.edu/~ito/Chinn-Ito_website.htm`

low-volatility regime. Output and foreign exchange rates are much more volatile under the high-volatility regime.

Thus, it is natural to ask how central banks should react when external volatility is high. While recent studies suggest that temporary central bank intervention can be desirable (Farhi and Werning, 2014), many studies favor an inflation-targeting interest rate rule (Galí and Monacelli, 2005), not to mention warning about causing macroeconomic instability if the central bank chooses to respond discretionarily. This divide among academic scholars has also influenced emerging market central banks–some of them favor temporary intervention, often referred to as "leaning against the wind," while others are strict inflation targeters (e.g. South Africa).

To answer this question, I develop a Markov-switching dynamic stochastic general equilibrium (MS-DSGE) model that features external shocks of time-varying volatility to study the monetary policy choices of central banks in emerging markets. Driven by larger foreign interest rate shocks, an economy fluctuates to a greater extent under the high-volatility regime. The central bank adopts an interest rate rule that responds to inflation, the output gap, and exchange-rate fluctuations, in which the response coefficients can vary under differing volatility regimes. Thus, the question becomes whether allowing this dimension of flexibility can improve welfare without causing macroeconomic instability.

One major contribution of this chapter is that it is the first to examine whether regime-switching monetary policy rules can ensure macroeconomic stability. I solve the MS-DSGE model using an algorithm from Farmer, Waggoner, and Zha (2011) and estimate it using Thailand data from 2001Q1 to 2015Q2. I examine a wide range of response coefficients in the interest rate rule and find that regime-switching interest rate rules are unlikely to cause macroeconomic instability.

In addition, I find that temporary intervention is effective in terms of stabilizing the economy in highly volatile periods. I characterize the "leaning against the wind" approach used by emerging market central banks as a regime-switching interest rate rule that responds to exchange rate fluctuations more aggressively under the high-volatility regime. I compare its performance with a constant-coefficient inflation-targeting rule. The impulse responses indicate that output and consumption fluctuate to a lesser extent under the former rule when the economy is hit by a large foreign interest rate shock.

Furthermore, welfare analysis shows that the optimal simple rule contains some "leaning against the wind" features. The optimal simple rule features no response to exchange-rate fluctuations under the low-volatility regime and a strong response under the high-volatility regime. This is because, under the low-volatility regime, the existence of productivity shocks and foreign demand shocks creates trade-offs between stabilizing inflation and the exchange rate, so the optimal operating rule should not respond to the exchange rate. Under the high-volatility regime, foreign interest rate shocks become the most important source of disturbance so monetary policy should respond to exchange rate fluctuations aggressively.

Finally, my research makes an additional contribution in studying the effect of temporary capital controls by allowing the central bank to adopt capital controls depending on the external volatility regime. Capital control is modeled as a quadratic portfolio adjustment cost, which reduces capital-flow volatility by inserting a wedge in the intertemporal Euler equation. It turns out that capital controls can effectively stabilize aggregate output and consumption in the short run but are welfare-reducing in the long run because households, anticipating possible capital controls in the future, will behave inefficiently under such circumstances.

The rest of the chapter is organized as follows. Section 1.2 reviews the related literature on open economy macroeconomics and emerging market economies. Section 1.3 studies foreign interest rates and empirically assesses the regime-switching assumption. Section 1.4 develops the MS-DSGE model used to study the problem as well as the solution algorithm. Section 1.5 summarizes the data source and the estimation results. Section 1.6 explains the main results of the research and section 1.7 concludes.

1.2 Related Literature

This research builds upon two existing strands of literature: studies on the analytical framework of the new open economy macroeconomics and studies on emerging market economies. In this chapter, I try to link the existing analytical framework with emerging market characteristics in order to achieve a better understanding of emerging market central banks and their policy choices.

The new open economy macroeconomics literature serves as the modeling foundation. Recent examples of the dynamic stochastic general equilibrium (DSGE) framework I employ in the chapter can be found in Clarida, Galí, and Gertler (2002) and Devereux, Lane, and Xu (2006). In particular, I adapt the modeling framework of Galí and Monacelli (2005), who develop a small open economy model with nominal rigidities. They suggest that it is optimal for a small open economy central bank to target domestic inflation and the output gap.

More recently, there have been some attempts to incorporate more emerging market features into the existing analytical framework. For instance, Aguiar and Gopinath (2007) suggest that emerging market economies face large nonstationary productivity shocks so that growth trend fluctuations constitute their business cycles. García-Cicco, Pancrazi, and Uribe (2010) use a small open economy with financial frictions to characterize business cycles in emerging markets.Liu and Spiegel (2015) study optimal monetary policy and capital account restrictions in a small open economy. Anand, Prasad, and Zhang (2015) find that an emerging economy's central bank should target headline inflation instead of core inflation.

Conceptually, the nature of many emerging market economies suggests that their central banks should not operate entirely based on the experience of advanced economies. For example, emerging market economies face prevalent foreign interest shocks and country-specific risk premium shocks, which are particularly important in the era after the global financial crisis due to unconventional monetary policy. Uribe and Yue (2006) find that interest rate shocks represent an important driver of business cycles in emerging countries, accounting for 30 percent to 42 percent of the variance in output. If emerging market central banks are reluctant to "import" monetary policy from abroad, they have to decide whether to adopt a flexible exchange-rate regime or impose capital controls, and a recent strand of research suggests that capital controls are necessary regardless of the exchange-rate regime (Rey, 2015). Edwards (2015) also finds similar results based on data from Latin America.

Another policy feature in emerging market economies is that capital controls are much more prevalent. One important reason that prudential capital controls are necessary is that households face pecuniary externalities. Bianchi (2011) develops a DSGE model with an occasionally binding collateral constraint and shows that macroprudential policy limits overborrowing and improves welfare. Similarly, Korinek (2011) differentiates prudential capital controls from traditional capital controls and argues that the former reduce the risk of financial crises. Apart from pecuniary externalities, there are alternative channels that make prudential capital controls appealing. Schmitt-Grohé and Uribe (2012) find that prudential capital controls are helpful for peggers because of downward nominal wage rigidity. Farhi and Werning (2014) prove that capital controls are welfare-improving even under a flexible exchange-rate regime because they smooth intertemporal terms of trade.

1.3 Foreign Interest Rate Shocks

Since foreign interest rate shocks are a major driving force of business cycles in emerging market economies and are directly responsible for volatile capital flows, I start by characterizing the foreign interest rate process. I follow Uribe and Yue (2006) and compute the real foreign interest rate for an emerging market economy by adding the real US interest rate and its country spread together.

I compute the real foreign interest rates for eight emerging market economies: Argentina, Brazil, Ecuador, Malaysia, Mexico, South Africa, Thailand, and Uruguay. The real US interest rate is derived from the T-bill rate and inflation while the country spread is retrieved from the JP Morgan Emerging Market Bond Index (EMBI). For all emerging market economies in the sample, country spreads account for a major share of the variations in foreign interest rates.

Since the foreign interest rate is assumed to be exogenous in my model and exhibits time-varying volatilities, I can estimate it separately using a regime-switching model.[2] I estimate the real foreign interest rate processes for the eight emerging market economies individually using a univariate AR(1) model with unobserved regime switches.

$$r_t = (1 - \rho_{r,s_t})\bar{r} + \rho_{r,s_t} r_{t-1} + \varepsilon_{t,s_t}, \quad \varepsilon_{t,s_t} \sim N(0, {\sigma^{r}_{s_t}}^2) \tag{1.1}$$

[2] Hamilton (1989) introduces regime-switching models into economics and I follow his algorithm when estimating the real interest rate processes.

Table 1.1: Estimates of Foreign Interest Rate Processes

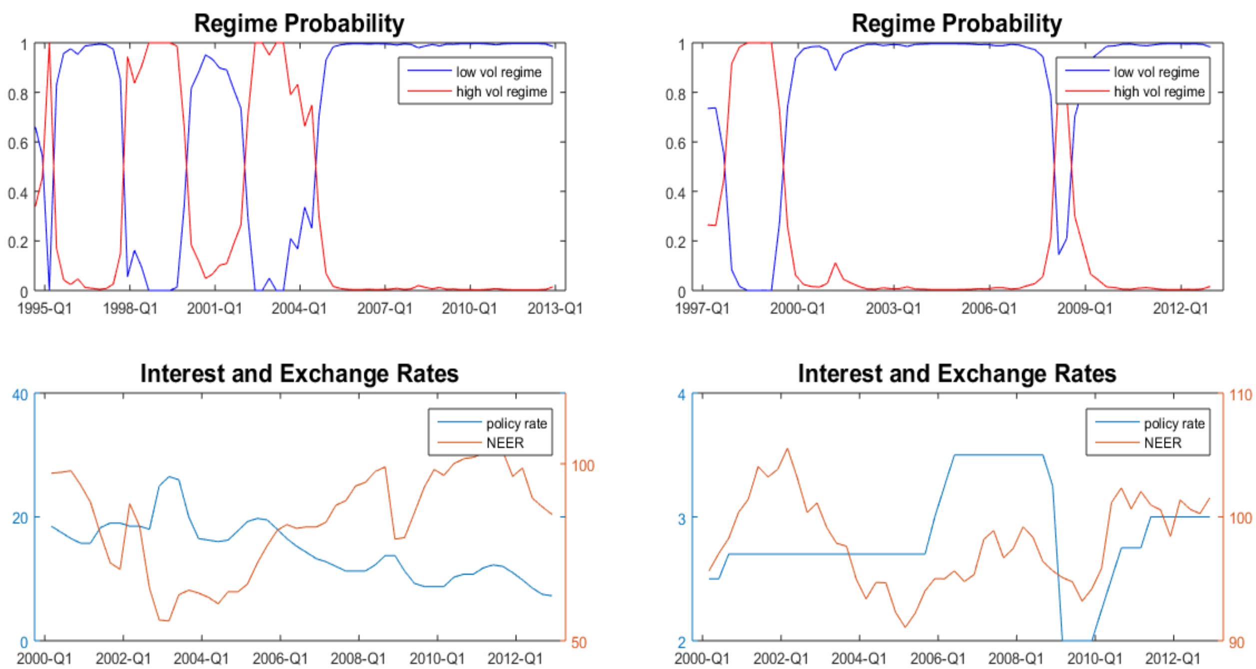
Country	ρ_r	σ^r_L	σ^r_H	p_L	p_H
Argentina	0.90	0.29	3.34	0.95	0.76
Brazil	0.94	0.14	0.81	0.94	0.83
Ecuador	0.83	0.28	2.36	0.93	0.76
Malaysia	0.93	0.11	0.44	0.96	0.80
Mexico	0.91	0.13	0.85	0.98	0.82
South Africa	0.95	0.07	0.22	0.84	0.85
Thailand	0.97	0.08	0.33	0.92	0.82
Uruguay	0.94	0.12	0.74	0.93	0.73

Notes: Real interest rates are computed by adding US interest rates and country spreads together. Data availability depends on individual countries. ρ_r is the constant autoregressive coefficient. σ^r_L and σ^R_H are the shock volatility under the low- and high-volatility regimes, respectively. p_L and p_H are the probabilities of remaining in the low- or high-volatility regime in the next period, respectively.

For all eight foreign interest rate series, the regime-switching estimation detects two regimes, under which shock volatility differs significantly. The autoregressive coefficients are found to be constant across the two regimes, so foreign interest rates can be modeled as AR(1) processes with time-varying volatility.

The parameter estimates are very similar across the eight emerging market economies and the results are presented in Table 1.1. The median probabilities of remaining in the low- or high-volatility regime in the next period are 0.95 and 0.80, respectively. The median standard deviations of foreign interest rate shocks are around 0.1 and 0.5 under the low- or high-volatility regimes, respectively.

Figure 1.1: Volatility Regime Probabilities and Policy Rate Responses



(a) Brazil

(b) Malaysia

Notes: In the regime probability plot, the red (blue) line represents the probability that an economy is under the high- (low-) volatility regime. The probabilities are estimated using the regime-switching model in equation (1.1) and at any time, the two probabilities add up to 1. In the interest and exchange rates plot, the blue line is the central bank policy rate and the red line is the nominal effective exchange rate (NEER) of a country.

Figure 1.1 visualizes the volatile regime switches in foreign interest rates and the corresponding central bank policy responses. I plot the probability of volatility regimes, the nominal effective exchange rates (NEER), and the policy rates separately for Brazil and Malaysia. As we can see, each country experiences several switches between the low- and high-volatility regimes. For example, Brazil encountered substantially higher foreign interest rates in 2002 and 2003 due to an increase in country spreads, accompanied by considerable currency depreciation. On the other hand, foreign interest rates dropped significantly after the federal reserve adopted unconventional monetary policy.

Notably, exchange rate fluctuations are larger under the high-volatility regime and policy rates also appear to be more responsive to foreign exchange rate fluctuations. This is consistent with the anecdotal evidence that emerging market central banks prefer "leaning against the wind" when external volatility is high.

1.4 Model

To study the implications of adopting regime-switching monetary policy rules in emerging market economies, I develop a small open economy model with nominal rigidities and foreign interest rates of time-varying volatilities. In contrast to the simplifying assumption of complete markets in Galí and Monacelli (2005), the home economy can access the international financial market only through risk-free borrowing and lending, which is subject to foreign interest rate shocks.

Foreign interest rates are characterized by a Markov process with two underlying regimes: the high-volatility regime and the low-volatility regime. Under the high-volatility regime, foreign interest rate shocks are larger whereas under the low-volatility regime they are smaller. Consequently, capital flows are more volatile under the high-volatility regime. I then study whether central banks should intervene during periods of volatile capital flows and, if so, what policy instruments they should use.

1.4.1 Households

The home economy consists of a large number of identical and infinitely-lived households that consume both domestically produced goods and foreign imports. The representative household maximizes the discounted stream of utility:

$$E_0 \sum_{t=0}^{\infty} \beta^t U(C_t, N_t) \tag{1.2}$$

where $\beta \in (0, 1)$ is the discount factor, C_t is the composite consumption of the representative household in period t, including home and foreign goods, and N_t is the labor supplied by the representative household. The utility function takes the form:

$$U(C_t, N_t) = \left(\frac{{C_t}^{1-\sigma}}{1-\sigma} - \psi \frac{{N_t}^{1+\phi}}{1+\phi} \right) \tag{1.3}$$

where σ is the risk-aversion coefficient, the parameter ψ is the inverse of the Frisch elasticity, and ϕ is the scaling factor. The composite consumption is defined as

$$C_t = (a^{\frac{1}{\eta}} {C_{H,t}}^{\frac{\eta-1}{\eta}} + (1-a)^{\frac{1}{\eta}} {C_{F,t}}^{\frac{\eta-1}{\eta}})^{\frac{\eta}{\eta-1}} \tag{1.4}$$

where $C_{H,t}$ represents home goods and $C_{F,t}$ represents foreign goods. The elasticity of substitution between home and foreign goods is given by $\eta \in (0, +\infty)$ and $a \in (0, 1)$ is the weight on home goods in the composite consumption index, which reflects the degree of home bias in preferences. The composite home good $C_{H,t}$ comprises a continuum of differentiated goods:

$$C_{H,t} \equiv \left(\int_0^1 C_{H,t}(j)^{\frac{\varepsilon-1}{\varepsilon}} dj \right)^{\frac{\varepsilon}{\varepsilon-1}} \tag{1.5}$$

where $\varepsilon > 1$ represents the elasticity of substitution between any two differentiated home goods.

1.4.2 Budget constraints

A representative household maximizes its lifetime utility given by equation (1.2) subject to the following budget constraint:

$$P_t C_t + e_t B_t^* + \frac{\psi_B}{2} e_t B_t^{*2} + B_t = W_t N_t + R_{t-1}^* e_t B_{t-1}^* + R_{t-1} B_{t-1} + T_t \tag{1.6}$$

where B_t and B_t^* represent one-period risk-free nominal bonds denominated in domestic and foreign currencies, respectively. The nominal exchange rate is denoted by e_t and the gross nominal interest rates for the two types of bonds are denoted by R_t and R_t^*, respectively. W_t is the nominal wage and and N_t is the labor supply. T_t contains lump sum taxes and transfers from the government and profits from firms.

In addition, ψ_B, a quadratic portfolio holding cost for foreign bond holdings, serves two purposes in the model. When no capital control is imposed, the value of this parameter is negligible, only to ensure the stationarity of the system (Schmitt-Grohé and Uribe, 2003). Alternatively, the central bank can impose capital controls to smooth international capital flows, which appears as a wedge in the intertemporal Euler equation (Chang, Liu, and Spiegel, 2015).[3]

The total expenditure needed to attain a consumption index C_t is given by P_tC_t where P_t is defined as

$$P_t = \left[aP_{H,t}^{1-\eta} + (1-a)P_{F,t}^{1-\eta}\right]^{\frac{1}{1-\eta}} \tag{1.7}$$

$P_{H,t}$, the price index of home goods, is defined as

$$P_{H,t} = \left[\int_0^1 P_{H,t}(j)^{1-\varepsilon} dj\right]^{\frac{1}{1-\varepsilon}} \tag{1.8}$$

[3] I assume that, in the baseline model, there is no capital control in place. The optimal capital control policy will be discussed as an extension. Notably, capital controls affect households' intertemporal decisions without altering their budget constraints; any tax revenues or subsidy costs will be transferred to households in a lump sum fashion.

1.4.3 Households' optimality condition

A set of intertemporal optimality conditions arises from the representative household's bond-holding decisions. The optimality condition derived from the holding of domestic currency denominated bond is given by:

$$E_t\left[\beta_t R_t\left(\frac{P_t}{P_{t+1}}\right)\left(\frac{C_{t+1}}{C_t}\right)^{-\sigma}\right] = 1 \tag{1.9}$$

The following optimality condition applies to the holding of foreign currency-denominated bonds:

$$E_t\left[\beta_t \frac{R_t^*}{1+\psi_B B_t^*}\left(\frac{q_{t+1}}{q_t}\right)\left(\frac{C_{t+1}}{C_t}\right)^{-\sigma}\right] = 1 \tag{1.10}$$

where ψ_B appears as a wedge in the Euler equation, as mentioned above. Without capital controls, the uncovered interest rate parity (UIP) holds in expectation. Thus, capital controls limit capital flows by reducing effective interest rate differentials.

Apart from consumption decisions, the representative household also decides how much labor to supply each period. The marginal utility of wage income equates to the marginal disutility of the labor supply.

$$\psi {C_t}^{\sigma} {N_t}^{\phi} = \frac{W_t}{P_t} \tag{1.11}$$

1.4.4 Production

Firms use a linear technology in labor, $Y_{H,t}(j) = A_t N_t(j)$, to produce home goods and they are subject to common productivity shock A_t, given by:

$$log(\frac{A_t}{\bar{A}}) = \rho_a log(\frac{A_{t-1}}{\bar{A}}) + \varepsilon_t^a, \quad \varepsilon_t^a \sim N(0, \sigma_a^2) \tag{1.12}$$

Following Calvo (1983), I assume that a fraction $\theta \in (0,1)$ of firms cannot change their prices in each period. The remaining firms choose optimal reset prices to maximize their discounted future profits.

$$\max_{P_{H,t}(j)} E_t \sum_{s=0}^{\infty} \{(\theta)^s Q_{t,t+k} \left[P_{H,t}(j) - MC_{H,t+s}\right] Y_{H,t+s}(j)\} \tag{1.13}$$

where MC denotes the marginal cost of production in nominal terms and $Q_{t,t+k}$ is the stochastic discount factor.

1.4.5 External variables

The small open economy is heavily influenced by the external environment through two major channels, foreign demand for home goods and the foreign interest rate. Aggregate demand for home goods is the sum of domestic and foreign demand, which is given by:

$$Y_{H,t} = a\left(\frac{P_{H,t}}{P_t}\right)^{-\eta} C_t + (1-a)\left(\frac{P_{H,t}}{P_{F,t}}\right)^{-\eta} C_t^* \tag{1.14}$$

where C_t^* is aggregate foreign demand, which is normalized such that in the steady state it is equal to the steady-state level of aggregate home consumption. I assume that aggregate foreign demand follows an AR(1) process given by:

$$log\left(\frac{C_t^*}{\bar{C}^*}\right) = \rho_c log\left(\frac{C_{t-1}^*}{\bar{C}^*}\right) + \varepsilon_t^c, \quad \varepsilon_t^c \sim N(0, \sigma_c^2) \tag{1.15}$$

More importantly, emerging market economies face recurrent episodes of persistent foreign interest rate shocks, leading to volatile capital flows. To capture this feature, I allow the foreign interest rate process to be regime-specific. Under the low-volatility regime, foreign interest rates follow an AR(1) process with a smaller persistence parameter and less variance in shocks. Under the high-volatility regime, the foreign interest rate process is more persistent and the shock variance is larger.

$$log\left(\frac{R_t^*}{\bar{R}^*}\right) = \rho_{r,s_t} log\left(\frac{R_t^*}{\bar{R}^*}\right) + \varepsilon_{t,s_t}^r, \quad \varepsilon_t^r \sim N(0, {\sigma_{s_t}^r}^2) \tag{1.16}$$

1.4.6 Regime switches

To capture the recurrent episodes of volatile capital flows in emerging market economies, I allow the economy to switch between two underlying regimes: the high-volatility regime (H) and the low-volatility regime (L). The regime switches according to a Markov chain and its transition matrix is denoted as Π, such that $\pi_{i,j}$ represents the probability of switching to the j^{th} regime from the i^{th} regime. The transition matrix Π is given by:

$$\Pi = \begin{pmatrix} p_{HH} & 1 - p_{HH} \\ 1 - p_{LL} & p_{LL} \end{pmatrix} \tag{1.17}$$

Consequently, the foreign interest rate process is characterized by persistence coefficient $\rho_{r,H}$ and shock standard deviation σ^r_H under the high-volatility regime, and $\rho_{r,L}$ and σ^r_L under the low-volatility regime.

More importantly, the central bank can choose whether to impose a regime-switching monetary policy or stick to a constant inflation-targeting rule. If the central bank operates differentially across regimes, its policy regimes can be characterized as regime-dependent response coefficients.

1.4.7 Monetary policy

Aggregate inflation is defined as $\pi_t = P_t/P_{t-1}$ and home goods inflation as $\pi_{H,t} = P_{H,t}/P_{H,t-1}$. The steady state is characterized by zero inflation.

The central bank determines the short-term nominal interest rate R_t according to a simple inflation-targeting rule, by which interest rates respond to inflation and possibly to exchange-rate fluctuations (see, e.g., Lubik and Schorfheide, 2007):

$$log\left(\frac{R_t}{\overline{R}}\right) = \rho\ log\left(\frac{R_{t-1}}{\overline{R}}\right) + (1-\rho)\left[\phi_\pi log\left(\frac{\pi_t}{\overline{\pi}}\right) + \phi_y log\left(\frac{Y_t}{\overline{Y_t}}\right) + \phi_e log\left(\frac{q_t}{q_{t-1}}\right)\right] \tag{1.18}$$

where $\bar{\pi}$, $\bar{Y}$, and $\bar{R}$ are the steady state values of inflation, output, and the nominal interest rate. The term ρ is the interest rate smoothing parameter. ϕ_π, ϕ_y and ϕ_e are the weights assigned by the central banker to the deviations of inflation and output from their steady-state levels and to fluctuations of the real exchange rate.[4] Setting the parameter ϕ_e at zero implies a pure inflation-targeting regime, under which the central bank responds only to inflation. In contrast, a positive ϕ_e indicates the will of stabilizing real exchange rate fluctuations.

When the coefficients in the monetary policy rule depend on the external volatility regime, I call it a regime-switching policy rule. The main goal of the chapter is to study whether regime-switching monetary policy rules are more desirable given that emerging market economies face time-varying external volatility.

1.4.8 Solution methods

MS-DSGE models have received increasing attention recently as they incorporate the richness of regime switches into a DSGE model. Davig and Leeper (2007) de-

[4]This formulation is in line with the stated objective of many emerging market central banks, namely "leaning against the wind".

velops a MS-DSGE model to study the interaction and regime switches of fiscal and monetary policy. Bianchi (2013) estimates a medium-scale MS-DSGE model with Bayesian techniques and finds repeated fluctuations of monetary policy between hawkish and dovish regimes. Farmer, Waggoner, and Zha (2011) and Foerster et al. (2014) develop powerful techniques to solve MS-DSGE models.

In this chapter, I use the minimal state variables solution algorithm developed by Farmer, Waggoner, and Zha (2011) due to its robustness and speed of convergence. The outline of the algorithm and my approach to implementing it are given below:

First, I log-linearize the system around its steady state for each specific regime and write the system of equations in the following form:

$$A(s_t)x_t = B(s_t)x_{t-1} + \Psi(s_t)\varepsilon_t + \Pi(s_t)\eta_t, \tag{1.19}$$

where the parameter matrices depend on the regime state in period t. x_t is a vector of endogenous and predetermined variables, ε_t is a vector of exogenous shocks, and η_t is a vector of expectational errors.

Second, I implement the algorithm in Farmer, Waggoner, and Zha (2011) and transform the problem into one of finding the roots of quadratic polynomial functions. Then x_t and η_t can be written as the linear transformation of x_{t-1} and ε_t, given by:

$$x_t = V_{s_t}F_{1,s_t}x_{t-1} + V_{s_t}G_{1,s_t}\varepsilon_t \tag{1.20}$$

$$\eta_t = -(F_{2,s_t}x_{t-1} + G_{2,s_t}\varepsilon_t) \tag{1.21}$$

where $V_{s_t}, F_{1,s_t}, F_{2,s_t}, G_{1,s_t}$, and G_{2,s_t} are matrices solved based on the quadractic polynomial functions. Equations (1.20) and (1.21) are solutions to the system characterized by (1.19).

Finally, there can be multiple minimal state variables solutions for a given MS-DSGE model. To find all solutions, I randomly select from a number of initial values and compute the corresponding solutions until they converge. Then, as suggested by Farmer, Waggoner, and Zha (2011), there is a mapping from the root of the equation to the solution of the model. According to Proposition 3.9, p.36 and Proposition 3.33, p.49 in Costa, Fragoso, and Marques (2005), the candidate solution is stationary (mean-square-stable) if and only if all eigenvalues of the matrix in equation (10) of Farmer, Waggoner, and Zha (2011) are inside the unit circle.

As a result, checking the stationarity of the solution is equivalent to checking the size of the dominant eigenvalue of that matrix. If there is only one solution with dominant eigenvalue smaller than 1, there is no need for selection. If there are multiple solutions with dominant eigenvalues smaller than 1, one can use the likelihood method and select the equilibrium that delivers the highest likelihood value with respect to the data. This is especially appealing when estimating the model using real data.

1.4.9 Welfare function

A well-defined micro-founded welfare criterion is needed in order to compare policy choices. In general, there are two major ways to evaluate welfare: the linear-quadratic approach and the second-order approximation approach. The linear-quadratic approach obtains an analytic expression of the welfare function by approximating the equilibrium conditions up to the first order and the welfare function up to the second order Rotemberg and Woodford (1997). However, it may sometimes generate spurious results because some important second-order terms are ignored (Kim and Kim, 2003).

Alternatively, Schmitt-Grohé and Uribe (2004, 2007) develop a numerical method to evaluate welfare under various policy environments by approximating the whole system of equations up to the second order. While this method is accurate, the lack of an analytic expression of the welfare function prohibits further theoretical analysis. Furthermore, it does not apply to MS-DSGE models.

In this chapter, I use the pure quadratic approximation method proposed by Benigno and Woodford (2012) to derive the welfare function analytically. To be more specific, I approximate the welfare function to the second order and eliminate all the first-order terms using equilibrium conditions. Unlike the traditional linear-quadratic method, the equilibrium conditions are approximated to the second order in order to get a pure quadratic approximation of the welfare function.

According to the derivation in Appendix A.2, the loss function based on the pure quadratic approximation can be written in the following fashion:

$$L_{t_0} = U_c \bar{C} E_{t_0} \sum \beta^t \left[\frac{1}{2} y_t' L_y y_t + y_t' L_e e_t + \frac{1}{2} l_{\hat{\pi}} (\hat{\pi}_t^H)^2 \right] + t.i.p. + O(||\xi||^3) \tag{1.22}$$

where $y_t = [\hat{y}_t, \hat{c}_t, \hat{p}_{H,t}, \hat{Q}_t]$ are endogenous variables, $e_t = [\hat{a}_t, \hat{i}_t^*, \hat{c}_t^*]$ are external shocks, and L_t, L_e, and $l_{\hat{\pi}}$ are matrices and the scalar derived in the appendix.

Thus, not only do output and inflation enter the loss function, the real exchange rate also plays a significant role, which is consistent with De Paoli (2009). Based on the loss function, I compare alternative policy choices in the MS-DSGE model.

1.5 Data and Estimation

I estimate my DSGE model using data from Thailand. I use Thailand data because Thailand was one of the first emerging market economies to adopt inflation targeting so using data from Thailand gives me a longer time series. The sample ranges from 2000Q1 through 2015Q2 because Thailand adopted inflation targeting in 2000. A thorough guide to MS-DSGE model estimation can be found in Bianchi (2013).

1.5.1 Data

I estimate the model using five observable data series: inflation, the GDP growth rate, the nominal effective exchange rate, the real effective exchange rate, and the domestic interest rate. All data are retrieved from the CEIC database. I use X-13 filter to compute the seasonally adjusted quarter-by-quarter GDP growth rate. To equate the number of observable variables with the number of shocks, I add two additional types of shocks which are common in the literature, i.e., monetary policy shocks and foreign inflation shocks.

1.5.2 Prior values

Calibrating such a model is challenging as there is no consensus on the values of some parameters for emerging market economies. As a result, I pick parameter values from the existing literature as the means of the prior distributions and use Bayesian methods to estimate the model. Prior means and posterior modes are summarized in Table 1.2. The time period in the model is equivalent to one quarter.

I choose $\beta = 0.995$, which is equivalent to the observed annual real interest rate of 2 percent. The prior mean of σ, the risk-aversion parameter, is set at 2, a value commonly used in the literature on emerging market economies (Aguiar and Gopinath, 2007; Anand, Prasad, and Zhang, 2015; García-Cicco, Pancrazi, and

Uribe, 2010). The share of home-produced tradable goods, denoted by a, is set at 0.7, which implies that home goods account for 70% of domestic consumption (Galí and Monacelli, 2005).

The elasticity of substitution between home and foreign goods is assumed to be 1 (Obstfeld and Rogoff, 2005). The Frisch elasticity $(1/\psi)$ is assumed to be $1/3$ (in other words, $\psi = 3$). For the monetary policy parameters, I use loose priors and choose $\rho = 0.5$, $\phi_\pi = 1.5$, $\phi_e = 0.25$, $\phi_y = 0.125$.

Lastly, I use the estimates of the foreign interest rate processes to pin down the parameter values that are regime-specific. For the persistence parameter of the foreign interest rate process, ρ_r, I set the value at 0.93 based on the median of the estimates. The standard deviations of shocks are set at (0.1) under the high- (low-) volatility regime.

1.5.3 Bayesian estimation

Based on the above-mentioned prior values, I implement Bayesian estimation using Thailand macroeconomic data from 2010Q1 - 2015Q2. I split the sample into two sub-samples, the pre-financial crisis period and the post-financial crisis period. The results are summarized in Table 1.2.

The estimates of structural variables are very close under both regimes while the interest rate rule parameters and shock parameters are very different, consis-

Table 1.2: Bayesian Estimation Results

Parameter	Prior		Posterior Mode	
	mean	*std. dev.*	*00Q1 - 07Q2*	*07Q3 - 15Q2*
β	0.995	0.005	0.996	0.996
σ	2	0.75	2.57	2.24
a	0.7	0.1	0.81	0.78
η	1	0.5	0.87	1.01
ψ	3	1	2.53	2.33
ρ	0.5	0.2	0.92	0.94
ϕ_π	1.5	0.5	1.93	1.28
ϕ_e	0.25	0.13	0.16	0.28
ϕ_y	0.125	0.07	0.08	0.09

Notes: Parameters are estimated using the Random-walk Metropolis algorithm with 100,000 draws. The prior distributions are borrowed from the existing literature.

tent with the regime-switching assumption. Based on the parameter values from Bayesian estimation results, I then compute the impulse responses and welfare outcomes under various policy choices.

1.6 Main Results

Based upon the model developed and estimated above, I now examine three aspects of the desirability of regime-switching policy rules. First, it is crucial to verify that regime-switching policy rules ensure macroeconomic stability. Otherwise, they are strictly dominated by any inflation-targeting rules that can achieve this goal. This can be done by examining the existence and uniqueness of rational-expectation equilibrium under a wide range of policy coefficients.

Second, it is useful to know whether regime-switching monetary policy rules would lead to more stable aggregate output when the home economy faces large foreign interest rate shocks. The major reason that emerging market central banks deviate temporarily from inflation-targeting rules and stabilize their exchange rates is that targeting inflation is not sufficient to stabilize the home economy. This can be analyzed by comparing impulse responses to foreign interest rate shocks under inflation-targeting rules and regime-switching rules.

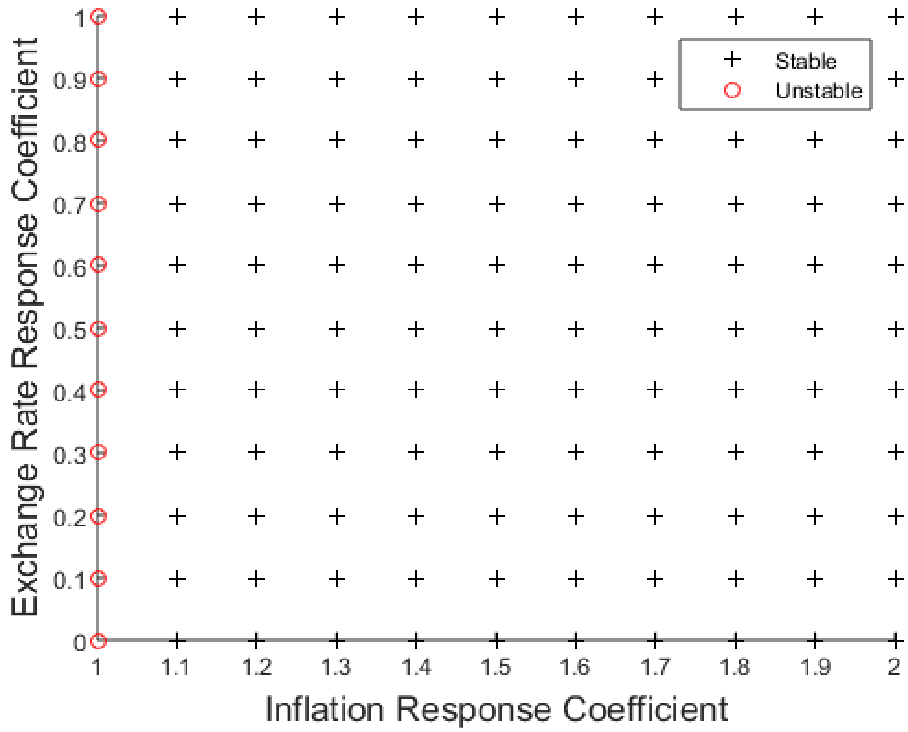
Lastly, it is important to understand the welfare outcomes when regime-switching policy rules are allowed. Using the method discussed above, I can approximate the welfare function up to the second order and numerically calculate the welfare levels under various types of policy rules. This allows me to study the welfare outcomes and search for the optimal simple rule.

1.6.1 Macroeconomic stability

A major advantage of operating monetary policy based on explicit interest rate rules is that it ensures macroeconomic stability. For example, the famous Taylor principle suggests that in order to ensure macroeconomic stability, the central bank should adjust interest rates more than one-to-one in response to changes in inflation rates (Davig and Leeper, 2007).

In practice, ensuring macroeconomic stability is not an easy task, as some seemingly reasonable monetary policy rules will in fact cause macroeconomic in-

Figure 1.2: Macroeconomic Stability under Varying Policy Coefficients



Notes: This figure shows the stability status of the economy conditional on varying values of inflation and exchange-rate response coefficients. A black plus sign means that the rational-expectation equilibrium uniquely exists while a red circle implies that the equilibrium is either non-unique or does not exist. The interest rate smoothing coefficient ρ is set at 0.7 and the inflation response coefficient ϕ_π at 2, which are plausible parameter values according to the estimation.

stability. For example, Uribe (2003) finds that targeting the real exchange rate can generate aggregate instability due to self-fulfilling expectations.

Using the model developed and estimated above, I examine the existence and uniqueness of the rational-expectation equilibrium under a wide range of policy coefficients. Generally speaking, macroeconomic stability is ensured under such regime-switching policy rules. A detailed example is given in Figure 1.2, in which I present the stability status under varying values of ϕ_π and ϕ_e, which are coefficients governing the interest rate response to inflation and exchange-rate fluctuations.

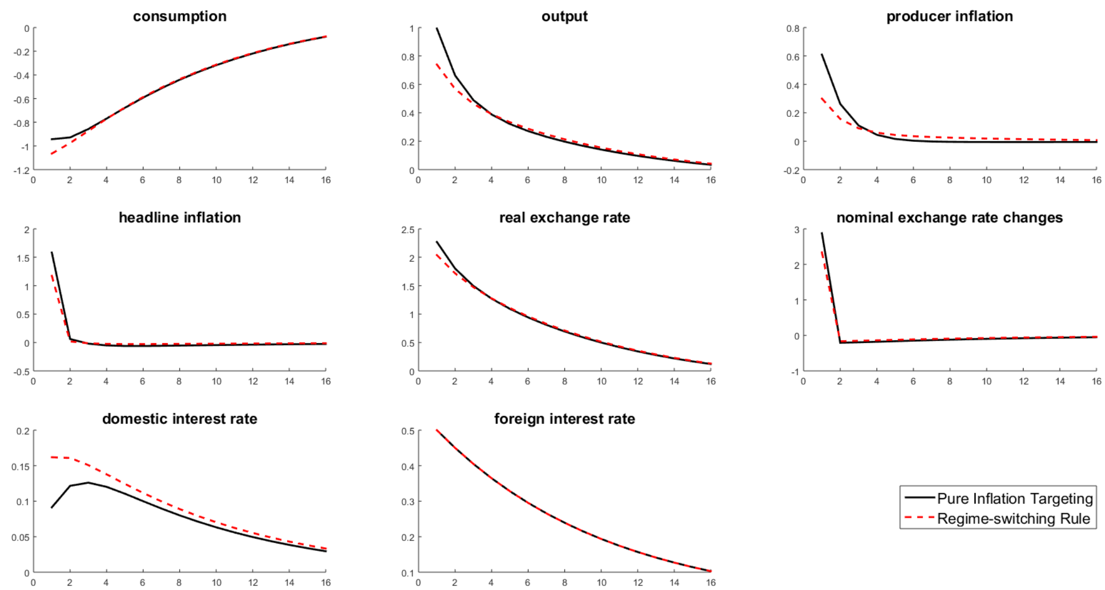
According to Figure 1.2, as long as the Taylor principle is met, namely, $\phi_\pi > 1$, macroeconomic stability is achieved. Thus, for an emerging market central bank, adopting regime-switching monetary policy rules is not going to impose any additional limits compared with pure inflation-targeting rules. This is a very desirable property.

1.6.2 Impulse responses

Since emerging market central banks are concerned with large economic fluctuations that are due to foreign interest rate shocks, I now examine whether temporarily smoothing exchange rates can effectively stabilize the domestic economy. To be more specific, I compare impulse response functions under the pure inflation-targeting rule and a regime-switching rule that temporarily smooths exchange rates. The home economy is under the high-volatility regime and faces a one-standard-deviation positive foreign interest rate shock, which can be thought of as a sudden stop. The impulse responses are plotted in Figure 1.3.

The impulse responses show that temporary exchange rate smoothing leads to a higher domestic interest rate, which smooths nominal and real exchange rates

Figure 1.3: Impulse Responses to a Positive Foreign Interest Rate Shock (High-volatility Regime)



Notes: This figure shows the responses of several variables to a one-standard-deviation foreign interest rate shock under the high-volatility regime. Two policy rules are considered. The black solid lines are impulse responses under the pure inflation-targeting rule and the red dashed lines represent impulse responses under the regime-switching rule (temporary exchange rate smoothing). The responses are all expressed as percentage deviations from the steady-state values of the corresponding variables. An increase in the exchange rate (both nominal and real) indicates depreciation.

as well as domestic inflation and output. A higher domestic interest rate reduces currency depreciation and capital outflows. It also stabilizes output by reducing producer inflation. Thus, monetary policy that temporarily smooths exchange rates can help stabilize aggregate output in the short run.

1.6.3 Welfare analysis of regime-switching monetary policy

While regime-switching monetary policy that temporarily smooths exchange rates can mitigate the fluctuation of aggregate output during periods of volatile capital flows, its desirability remains questionable unless its welfare properties are well understood.

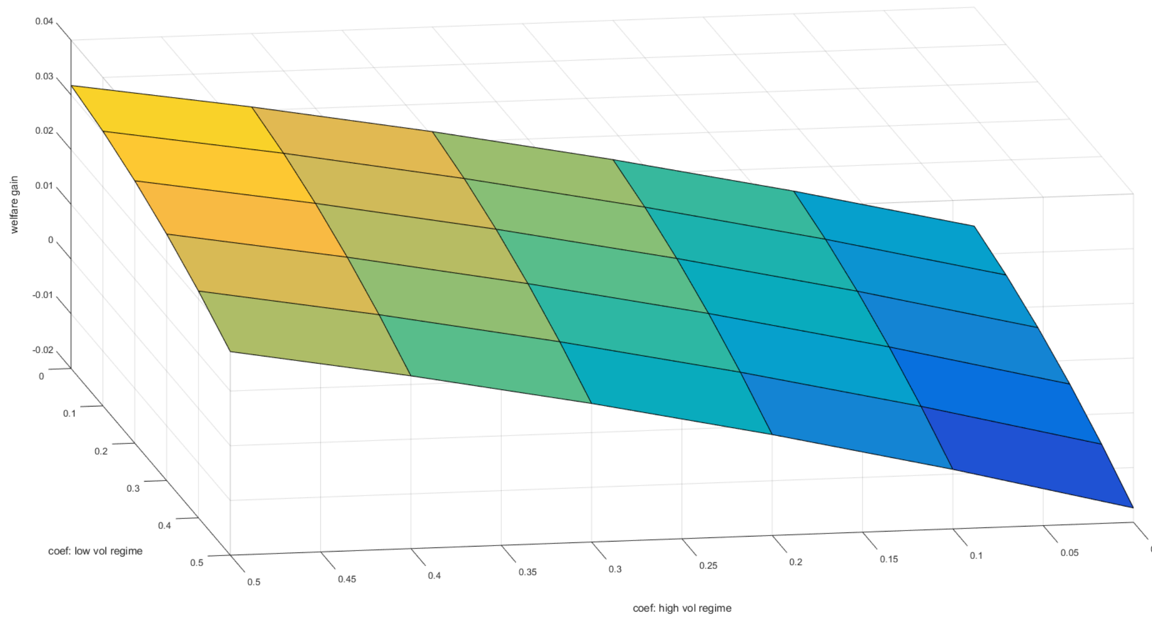
Conceptually, regime-switching monetary policy that temporarily smooths exchange rates should be welfare-improving compared with pure inflation-targeting rules because large foreign interest rate shocks cause volatile capital flows and large fluctuations in net exports. As a result, the home economy incurs welfare loss because of inefficient fluctuations in the terms of trade due to nominal rigidities. By temporarily smoothing exchange rates, emerging market central banks can smooth production and consequently stabilize the terms of trade.

Using the method explained above, I approximate the welfare function up to the second order and compute welfare outcomes under various monetary policy rules. In particular, I look for the optimal simple rule by searching for the coefficient combination that maximizes welfare.[5]

There is one particularly interesting feature of the pattern of optimal monetary policy. If I control for the other coefficients and vary the response to exchange-rate fluctuations under contrasting volatility regimes, it is clear that the welfare

[5] Detailed results are available upon request. I use constrained optimization methods to search for the optimal simple rule.

Figure 1.4: Welfare Gains under Various Regime-switching Policy Coefficients



Notes: This figure shows the relative welfare gains under various values of ϕ_e. The interest rate smoothing coefficient ρ is set at 0.7, the inflation response coefficient ϕ_π is set at 2, and the output gap response coefficient ρ_y is set at 0, which are plausible parameter values according to the estimation. The two axes on the plane correspond to the exchange rate response coefficients under the high-volatility regime and the low-volatility regime. The vertical axis displays the relative welfare gain. The result suggests that welfare is higher if ϕ_e is zero under the low-volatility regime and very high under the high-volatility regime. The results are robust under alternative parameter values.

level is higher when there is no response to exchange-rate fluctuations under the low-volatility regime and strong response under the high-volatility regime. This relationship is shown in Figure 1.4.

In fact, the optimal simple rule contains some "leaning against the wind" features as it suggests that the central bank should respond to exchange-rate fluctuations only under the high-volatility regime. This is because, under the low volatility regime, the existence of productivity shocks and foreign demand shocks creates trade-offs between stabilizing inflation and the exchange rate, so the optimal operating rule should not respond to the exchange rate. Under the high-volatility regime, however, foreign interest rate shocks become the most important source of disturbance so monetary policy should respond to exchange-rate fluctuations aggressively.

1.6.4 Capital controls

In the baseline model, I assume that no capital controls are imposed and households can freely borrow and save via the international financial market. However, many emerging market central banks impose temporary capital controls when facing volatile capital flows and it is important to understand the consequences of such intervention.

I model capital controls as quadratic portfolio adjustment costs when households change their bond holdings $\Gamma_t(B_t^*, B_{t-1}^*) = \psi_B(B_t^* - B_{t-1}^*)^2$. Capital controls reduce capital flow volatility by inserting a wedge in the intertemporal Euler equation, as shown below. Notably, any costs or revenues from capital controls are transferred to households in lump sum fashion so that capital controls have no wealth effect.

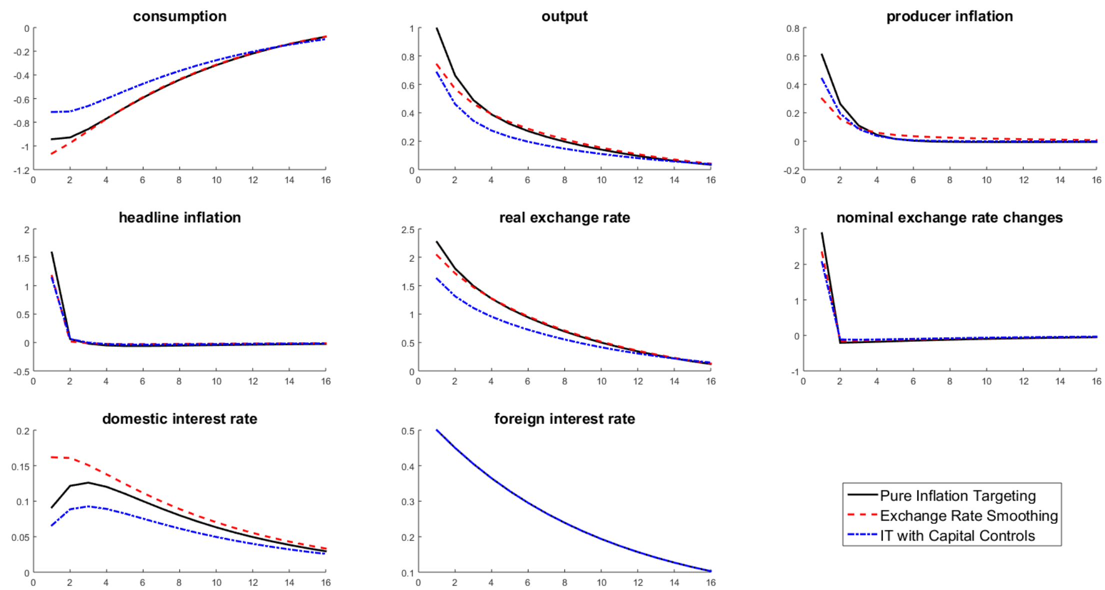
$$E_t\left\{\beta_t\left(\frac{C_{t+1}}{C_t}\right)^{-\sigma}\left[\frac{R_t^*}{1+\psi_B(B_t^*-B_{t-1}^*)}\frac{q_{t+1}}{q_t}-\frac{R_t}{\pi_{t+1}}\right]\right\}=0 \tag{1.23}$$

I now use the extended model to study the implications of imposing temporary capital controls. First, temporary capital controls will not jeopardize macroeconomic stability. Furthermore, imposing temporary capital controls can effectively stabilize aggregate output and consumption when the home economy faces large foreign interest rate shocks. This can be found in the impulse responses shown in Figure 1.5.

According to Figure 1.5, capital controls are much more effective at stabilizing aggregate output and consumption because they substantially reduce capital flows in the short run. The wedge placed in the intertemporal Euler equation gives the central bank a certain degree of flexibility as it does not need to adjust the domestic interest rate to minimize capital flows. With the adjustment cost, households are no longer as willing to save or borrow in foreign currency denominated bonds, so aggregate output and consumption are less volatile given temporary capital controls.

I then study the welfare effect of capital controls by allowing the central bank to incorporate capital controls as part of the regime-switching policy rules and impose them only under the high-volatility regime. It turns out that capital controls are welfare-reducing because households, anticipating possible capital controls in the future, will behave inefficiently under such circumstances. Detailed welfare comparisons are available upon request.

Figure 1.5: Impulse Responses to a Positive Foreign Interest Rate Shock (with Capital Controls)



Notes: This figure shows the responses of several variables to a one-standard-deviation foreign interest rate shock under the high-volatility regime. Three policy rules are considered. The black solid lines are impulse responses under a pure inflation-targeting rule, the red dashed lines represent impulse responses under a temporary exchange-rate smoothing rule, and the blue dash-dot lines show impulse responses under an inflation-targeting rule with temporary capital controls. The responses are all expressed as percentage deviations from the steady-state values of the corresponding variables. An increase in the exchange rate (both nominal and real) indicates depreciation.

1.7 Concluding Remarks

Emerging market economies frequently experience volatile capital flows and considerable exchange-rate fluctuations caused by large foreign interest rate shocks, so it is natural to ask how central banks should react when external volatility is high. Using data from emerging market economies, I develop a Markov-switching dynamic stochastic general equilibrium (MS-DSGE) model that features external shocks of time-varying volatility to study their monetary policy choices.

I find that by allowing the response coefficients in the interest rate rule to vary according to the regime of external volatility, the central bank can improve welfare while maintaining macroeconomic stability. The optimal simple rule suggests that the central bank should target inflation when external volatility is low and stabilize exchange rates when it is high, which is akin to the "leaning against the wind" approach adopted by many emerging market central banks. Temporary capital controls are effective in terms of short-term stabilization but are inferior in terms of welfare outcomes.

One interesting direction for future research would be relaxing the assumption of perfect information between households and the central bank. The first scenario would be that the state of external volatility is observable but households do not have full information of the monetary policy rule under this regime, so they have to learn from the observed policy rates. This will no doubt reduce the effectiveness of monetary policy and it is a very realistic scenario in emerging market economies given the weak reputation of the central banks.

The second scenario would be that the state of external volatility is unobservable but the policy regime is, so households learn the state of the economy from the central bank policy regime. If so, policy regime switches can be potentially detrimental because central banks may create and amplify economic crises by making the state of the economy explicit. This is also possible given information frictions in emerging market economies.

CHAPTER 2

WHAT MEASURE OF INFLATION SHOULD AN EMERGING MARKET CENTRAL BANK TARGET?

2.1 Introduction

Most central banks view low and stable inflation as a primary, if not dominant, objective of monetary policy. In the existing literature, the choice of price index to target has been guided by the idea that inflation is a monetary phenomenon. Core inflation (excluding food, energy, and other volatile components from headline CPI) has been viewed as the most appropriate measure of inflation since fluctuations in food and energy prices represent supply shocks and are non-monetary in nature (Wynne, 2008). Moreover, since these shocks are transitory, highly volatile, and do not reflect changes in the underlying rate of inflation, they should not be a part of the targeted price index (Mishkin, 2007, 2008).

Previous authors have used models with price and/or wage stickiness to show that targeting core inflation maximizes welfare. Existing models have looked at complete market settings where price stickiness is the only distortion (besides monopoly power). Infrequent price adjustments cause mark-ups to fluctuate and also distort relative prices. In order to restore the flexible price equilibrium, central banks should try to minimize these fluctuations by targeting sticky prices (Goodfriend and King, 1997, 2001).

Using a New Keynesian model, Aoki (2001) demonstrates that targeting inflation in the sticky price sector leads to macroeconomic stability and welfare maximization. Targeting core inflation is equivalent to stabilizing the aggregate output gap as output and inflation move in the same direction under complete markets. Benigno (2004) argues that in a common currency area the central bank should target an index that gives higher weight to inflation in regions with a higher degree of nominal rigidity, effectively ignoring exchange rate and commodity price fluctuations. In a more general multi-sector setting, Mankiw and Reis (2003) show that, in order to improve the stability of economic activity, the targeted "stability" price index should put more weight on sectors that have sluggish price adjustment, are more procyclical, and have a smaller weight in the consumer price index.

The results from the prior literature generally rely on the assumption that markets are complete (allowing households to fully insure against idiosyncratic risks). The central bank then only needs to tackle the distortions created by price stickiness. However, in emerging market economies, a substantial fraction of agents are unable to smooth their consumption in a manner consistent with the permanent income hypothesis. Moreover, emerging market economies have other structural differences from advanced economies, including the relatively high share of food in household consumption expenditures.

In this chapter, I provide an analytical framework for determining the optimal price index for emerging market central banks to target. The chapter makes three main contributions. First, it generalizes the benchmark results of Aoki (2001) and Benigno (2004) by developing a model that encompasses their frameworks. Second, it shows that incomplete financial markets and other characteristics of emerging market economies substantially alter the key results. Third, it derives optimal price indexes and compare them with feasible rules such as headline inflation targeting that also improve welfare relative to core inflation targeting but are easier for central banks to communicate and implement.

My model has three sectors to make it more representative of the structures of emerging market economies. First, the food (or informal) sector, which comprises a large fraction of the economy and where prices are flexible. Workers in this sector live hand-to-mouth, i.e., they have no access to credit markets and simply consume their current labor income. Second, the sticky price (or formal) sector that is subject to productivity and mark-up shocks, and where workers do have access to credit markets. Third, a sector that is open to foreign trade and where prices are flexible but also highly volatile. This sector, which proxies for the commodity-producing sector, faces large external shocks.

Financial frictions that result in consumers being credit constrained have not received much attention in models of inflation targeting. When markets are not complete and agents differ in their ability to smooth consumption, their welfare depends on the nature of idiosyncratic shocks. Thus, this model also allows me to analyze the welfare distribution under alternative inflation targeting rules. Under incomplete markets, household income, which is influenced by the nature of shocks and the price elasticity of the demand for goods, matters for consumption choices. For instance, a negative productivity shock to a good with a low price elasticity of demand could increase the income of net sellers of that good and raise the expenditure of net buyers of that good.

My model incorporates other important features relevant to emerging market economies. In these countries, expenditure on food constitutes 40-50 percent of household expenditures, compared to 10-15 percent in advanced economies. Low price and income elasticities of food expenditures as well as low income levels make the welfare of agents in emerging market economies more sensitive to fluctuations in food prices. These features imply that agents factor in food price inflation while bargaining over wages, thus affecting broader inflation expectations (Walsh, 2011). Thus, in emerging market economies even inflation expectation targeting central banks must take into account food price inflation.

The key result is that in the presence of financial frictions targeting headline CPI inflation improves aggregate welfare relative to targeting core inflation (i.e., inflation in the sticky price sector). Lack of access to financial markets makes the demand of credit-constrained consumers insensitive to interest rates. These consumers' demand depends only on real wages, establishing a link between aggregate demand and real wages. Thus, the relative price of the good produced in the flexible price sector not only affects aggregate supply but, through its effects on real wages, also influences aggregate demand.

My model allows me to compute optimal price indexes that maximize welfare. The optimal price index also includes a positive weight on food prices but, unlike headline inflation, generally assigns zero weight to import prices. This is because agents in that sector have access to financial markets and, unlike in the case of food, the price elasticity of the demand for goods produced in this sector is high.

These results differ from those of the prior literature based on complete markets settings. For instance, in Aoki's (2001) model, relative prices of the flexible price sector only appear as a shift parameter of inflation in the sticky price sector. Under incomplete markets, by contrast, the central bank has to respond to price fluctuations in the flexible price sector in order to manage aggregate demand. Financial frictions break the comovement of inflation and output, implying that stabilizing core inflation no longer stabilizes the output gap. Thus, in the presence of financial frictions, targeting a broader measure of inflation improves welfare.

In related work, Catão and Chang (2010) show that, for a small open economy that is a net buyer of food, the high volatility of world food prices causes headline CPI inflation targeting to dominate core CPI inflation targeting. Adding this feature would strengthen the results but make my model less general since few emerging market economies import a large share of their food consumption. Frankel (2008) argues that a small commodity-exporting economy should target the export price index in order to accommodate terms of trade shocks. The results suggest that ignoring sectors with nominal rigidities and targeting this set of flexible prices, which has a small weight in the domestic CPI, would reduce welfare.

The chapter is organized as follows. Section 2.2 contains some empirical facts to further motivate the structure of the model and its relevance to emerging market economies. Section 2.3 outlines the main features of the model and contrasts them with the prior literature. Section 2.4 presents the main results and Section 2.5 contains various sensitivity experiments to check the robustness of the baseline results and also presents some extensions of the basic model. Section 2.6 concludes the chapter.

2.2 Basic Stylized Facts

I first discuss some stylized facts that are relevant to monetary policy formulation in emerging countries, starting with the share of food in household consumption expenditures and measures of the elasticity of food expenditures. Engel's law states that as average household income increases, the average share of food expenditure in total household expenditure declines. When this idea is extended to countries, poorer countries would be expected to have a higher average share of food expenditure in total household expenditure. In Table 2.1, I present recent data on shares of food expenditure in total expenditure for selected emerging and advanced economies. As expected, expenditure on food constitutes a much larger share of total household expenditure in emerging relative to advanced economies.

Moreover, the income elasticity of food in emerging market economies is on average twice as large as that in advanced economies (0.63 versus 0.30 for a selected group of economies). The average price elasticity of food is much lower

Table 2.1: Share of Food Expenditure in Total Household Expenditure

Emerging Economies	*Food Expenditure*	*Advanced Economies*	*Food Expenditure*
Indonesia	53.0	Japan	14.7
Vietnam	49.8	Germany	11.5
India	48.8	Australia	10.8
China	36.7	Canada	9.3
Russia	33.2	United Kingdom	8.8
Malaysia	28.0	USA	5.7
Average	**41.6**	**Average**	**10.1**

Source: Household Surveys, CEIC, International Food Consumption Patterns Dataset, Economic Research Service, USDA and authors' calculations.
Notes: Data for emerging market economies are for 2005 while for advanced economies data are for 2006. Expenditure on food includes expenditure on food consumed at home only and does not include expenditure on beverages and tobacco.

in absolute terms than the typical assumption of a unitary price elasticity, suggesting that food is a necessary good. As the share of expenditure on food is high in emerging market economies, the price elasticity of food is higher in these economies (average of about -0.38) but still lower than the value normally used in the literature. Low price and income elasticities of the demand for food have considerable significance for the choice of price index.

To examine the extent of credit constraints in emerging countries, Table 2.2 presents data from the World Bank (Demirgüç-Kunt and Klapper, 2012) on the percentage of the adult population with access to formal finance (the share of the population using formal financial services) in emerging countries. These data

Table 2.2: Composite Measure of Access to Financial Services in Emerging Economies

Selected Economies	*Percent with Access*	*Selected Economies*	*Percent with Access*
Argentina	33	Nigeria	30
Brazil	56	Philippines	27
Chile	42	Poland	70
China	64	Russia	48
India	35	South Africa	54
Indonesia	20	Thailand	73
Kenya	42	Turkey	58
Malaysia	66		
Median (29 Emerging Economies): 42		**Median (27 Advanced Economies): 96**	

Source: Global Findex Database, World Bank, 2011.
Notes: The composite indicator measures the percentage of the adult population with access to an account with a financial intermediary. The table only shows data for a selected group of individual emerging market economies. Reported medians are based on a larger sample of emerging and advanced economies available in the database.

show that, on average, more than half of the population in emerging countries lacks access to the formal financial system. By contrast, in advanced economies, nearly all households have such access.

Finally, note that both food and nonfood inflation are higher on average in emerging economies than in advanced economies. In the former group, food inflation is more volatile than nonfood inflation, consistent with the notion that food prices are more flexible than prices of other goods. Innovations to food price inflation are also more volatile than innovations to nonfood inflation. These observations are consistent with other evidence that headline inflation is more volatile than core inflation in both emerging and advanced economies (Anand and Prasad, 2010). The two measures of inflation exhibit a high degree of persistence in both sets of economies and, contrary to conventional wisdom, food price shocks tend to be quite persistent in emerging market economies (also see Walsh, 2011).

The main observations from this section are that, relative to households in advanced economies, those in emerging market economies have a higher share of food expenditures in total consumption expenditures, a higher income elasticity and lower price elasticity of food expenditures, and significantly lower access to formal financial institutions. These features potentially have implications for households' responses to changes in monetary policy.

2.3 Model

In this section, I develop a small open economy model incorporating features that are particularly relevant for emerging market economies. To examine whether the existing results about optimal inflation targeting are affected by these features, I adopt a model setting that is otherwise standard but broad enough to encompass features that previous authors have focused on.

2.3.1 Households

The economy consists of a continuum of infinitely-lived households of two types: (i) measure $\lambda > 0$ of households producing food, the flexible price domestic good and (ii) measure $1 - \lambda$ of households producing a continuum of monopolistically produced sticky price goods (nonfood) for domestic consumption and a flexible price good for export (nonfood exports). My model is thus more general than that of Aoki (2001), which is for a closed economy, and allows for comparisons with Benigno's (2004) open economy setting. The model also embeds other key features of both Benigno (2004) and Mankiw and Reis (2003), whose models include multiple sectors with varying degrees of price rigidity.

I assume that labor is immobile across the food and nonfood sectors.[1] The representative household, denoted by the superscript i, is indexed by f (food sector) and n (nonfood sector). Household i maximizes the discounted stream of utility:

$$E_0 \sum_{t=0}^{\infty} \beta^t [U(C_t^i, N_t^i)] \tag{2.1}$$

where $\beta \in (0, 1)$ is the discount factor. The utility function takes the form:

$$U(C_t^i, N_t^i) = u(C_t^i) - v_i(N_t^i), \qquad i \in \{f, n\} \tag{2.2}$$

[1]This assumption reflects the large inter-sectoral wage differentials in emerging market economies. Galí, López-Salido, and Vallés (2004) demonstrate that, even with free labor mobility, financial frictions lead to similar results as ours (aggregate demand increasing when the central bank raises the policy interest rate).

where $u(C_t^i)$ is the utility of consumption and $v_i(N_t^i)$ is the disutility of labor supply. C_t^i is the composite consumption index of household i in period t, including food and nonfood goods. It is defined as

$$C_t^i = \left[\gamma^{\frac{1}{\eta}}(C_{f,t}^i - C^*)^{\frac{\eta-1}{\eta}} + (1-\gamma)^{\frac{1}{\eta}}(C_{n,t}^i)^{\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}} \tag{2.3}$$

where $C_{f,t}^i$ represents food and $C_{n,t}^i$ is the total nonfood good, comprising both domestically produced sticky price nonfood goods ($C_{s,t}^i$) and imported nonfood goods ($C_{m,t}^i$). The composite index is given by

$$C_{n,t}^i = \left[\zeta^{\frac{1}{\xi}}(C_{m,t}^i)^{\frac{\xi-1}{\xi}} + (1-\zeta)^{\frac{1}{\xi}}(C_{s,t}^i)^{\frac{\xi-1}{\xi}}\right]^{\frac{\xi}{\xi-1}} \tag{2.4}$$

$C_{s,t}^i$ is a continuum of the differentiated goods, given by:

$$C_{s,t}^i = \left[\int_0^1 c_{s,t}^i(z)^{\frac{\theta-1}{\theta}} dz\right]^{\frac{\theta}{\theta-1}} \tag{2.5}$$

The elasticity of substitution between the flexible price and sticky price goods is given by $\eta \in (0, +\infty)$ and $\gamma \in (0, 1)$ is the weight on food in the consumption index. $\zeta \in (0, 1)$ is the share of imported nonfood goods in the nonfood consumption index, and $\xi \in (0, +\infty)$ is the elasticity of substitution between domestic nonfood and imported nonfood goods. $\theta > 1$ is the elasticity of substitution between any two differentiated goods.

Since food is a necessity, households must consume a minimum amount C^* of food for survival. I assume that all households always have enough income to buy the subsistence level of food. Even though this constraint does not bind, it alters the elasticity of substitution between food and nonfood and the marginal utility of food and nonfood consumption. This is one important departure from previous models that are mostly relevant for advanced economies, where food is a modest share of overall household expenditures.

The utility of consumption is given by $U(C_t^i) = (C_t^i)^{(1-\sigma)}/(1-\sigma)$, where σ is the risk aversion factor. The disutility of labor supply for households in the food sector is given by $v_f(N_t^f) = \phi_n^f(N_t^f)^{(1+\psi)}/(1+\psi)$, where the parameter ψ is the inverse of the Frisch elasticity and ϕ_n^i is the scaling factor. As households in the nonfood sector provide labor to sticky price firms (s) and export sector firms (x), aggregate labor supply is given by $v_n(N_t^n) = \phi_n^n[\int_0^s \frac{N_t^s(m)^{1+\psi}}{1+\psi}dm + \int_s^1 \frac{N_t^x(m)^{1+\psi}}{1+\psi}dm]$, where s is the share of nonfood households that work in the sticky price sector.[2]

2.3.2 Budget constraints and financial markets

This section highlights the key difference between my model and those of previous authors who have studied optimal inflation targets. Households in the flexible price sector (food sector) do not have access to financial markets and they consume their wage income in each period.[3] So these households are akin to "rule of

[2]This specification implies local labor markets for the sticky price and export sectors and perfect risk-sharing among households in the nonfood sector (Ferrero, Gertler, and Svensson, 2010).

[3]Data in Demirgüç-Kunt and Klapper (2012) show that, in less developed economies, access to formal financial institutions is at least 10 percentage points lower in rural areas compared to urban

thumb" consumers.[4] A representative household in the food sector maximizes its lifetime utility given by equation (2.1) subject to the budget constraint:

$$P_t C_t^f + P_{f,t} C^* = W_{f,t} N_t^f \tag{2.6}$$

where $W_{f,t}$ is the nominal wage in the food sector. The total expenditure to attain a consumption index C_t^f is given by $P_t C_t^f$ where P_t is defined as

$$P_t = \left[\gamma P_{f,t}^{1-\eta} + (1-\gamma) P_{n,t}^{1-\eta}\right]^{\frac{1}{1-\eta}} \tag{2.7}$$

$P_{f,t}$ denotes the price of food and $P_{n,t}$, the price index of nonfood goods, is given by

$$P_{n,t} = \left[\zeta P_{m,t}^{1-\xi} + (1-\zeta) P_{s,t}^{1-\xi}\right]^{\frac{1}{1-\xi}} \tag{2.8}$$

and $P_{s,t}$ is the Dixit-Stiglitz price index defined as

$$P_{s,t} = \left[\int_0^1 X_t(z)^{1-\theta} dz\right]^{\frac{1}{1-\theta}} \tag{2.9}$$

Households in the nonfood sector provide labor to firms in both the sticky price sector and the export sector. They can buy one-period nominal bonds and

areas. Basu and Srivastava (2005) document that 80 percent of individuals in India's agricultural sector have no access to formal finance.

[4]There is no storage technology in the model. In addition to keeping the model tractable, this could be seen as reflecting the constraints that rural households in emerging market economies face in getting access to the formal financial system for both borrowing and saving purposes.

foreign bonds to smooth their consumption. A representative household in this sector maximizes lifetime utility given by equation (2.1) subject to the following budget constraint

$$\begin{aligned} & P_t C_t^n + P_{f,t} C^* + B_t + e_t B_t^* + \tfrac{\psi_B}{2} B_t^{*2} \\ \leq \quad & W_{s,t} \int_0^s N_t^s(m) dm + W_{x,t} \int_s^1 N_t^x(m) dm + R_{t-1} B_{t-1} + e_t R_{t-1}^* B_{t-1}^* + \Pi_t^s \end{aligned} \tag{2.10}$$

where B_t and B_t^* represents the quantity of one-period nominal risk free discount bonds denominated in domestic and foreign currency, respectively. The gross nominal interest rates for those two types of bonds are denoted by R_t and R_t^*, respectively.[5] $W_{x,t}$ and $W_{s,t}$ are the nominal wages in the export and sticky price sectors and N_t^x and N_t^s are the labor supply in these two sectors. Π_t^s is the profit from firms in the sticky price sector.

2.3.3 Production

Each household in the food sector owns one firm and produces food using a linear technology in labor $y_{f,t} = A_{f,t} N_t^f$, subject to a common productivity shock $A_{f,t}$. Firms in this sector are price takers and, given a market price $P_{f,t}$, the zero profit condition determines labor demand.

Similarly, firms in the sticky price sector use a linear technology in labor $y_{s,t}(z) =$

[5] I also include a small quadratic portfolio holding cost for foreign bond holdings, as suggested by Schmitt-Grohé and Uribe (2003), only to induce stationarity.

$A_{s,t}N_t^s(z)$ and are subject to a common productivity shock $A_{s,t}$. Following Calvo (1983), I assume that a fraction $\alpha \in (0,1)$ of firms cannot change their price in each period. Firms that are free to change the price at time t choose a price X_t to maximize the discounted profit stream given by:

$$\max_{X_t(z)} E_t \sum_{j=0}^{\infty} (\alpha\beta)^j Q_{t,t+j} \left[y_{t,t+j}^s(z)(X_t(z) - MC_t^s) \right] \tag{2.11}$$

where $Q_{t,t+j}$ is the stochastic discount factor, X_t is the price of the variety produced by firm z, and $y_{t,t+j}^s$ is the output of firm in period $t+j$ when it has set its price in period t. Furthermore, the marginal cost is given by $MC_t^s = \frac{W_t^s}{A_t^s}$.

Firms in the export sector also use a linear technology $y_{x,t} = A_{x,t}N_t^x$ and face an exogenous price level every period. Firms in this sector are assumed to be price takers. Import prices are exogenous and follow the law of one price. The terms of trade shock, which links import and export prices, determines the export price. Thus, $P_{x,t} = S_t P_{m,t}$, where S_t is the terms of trade. Given export prices, the firms' cost minimization problem determines wages and, therefore, the labor demand in the sector.

2.3.4 Inflation and monetary policy rule

Headline inflation is defined as $\pi_t = \frac{P_t}{P_{t-1}}$, gross inflation in the sticky price sector as $\pi_{s,t} = \frac{P_{s,t}}{P_{s,t-1}}$, and gross imported goods inflation is defined as $\pi_{m,t} = \frac{P_{m,t}}{P_{m,t-1}}$. The steady state is characterized by constant prices (zero inflation) and no price stickiness in the economy. The central bank sets the short-term nominal interest rate (R_t) according to the following version of a Taylor (1993) rule:

$$log\left(\frac{R_t}{\bar{R}}\right) = \rho\ log\left(\frac{R_{t-1}}{\bar{R}}\right) + (1-\rho)\left[\phi_\pi log\left(\frac{\pi_t^*}{\bar{\pi}}\right) + \phi_y log\left(\frac{y_t}{\bar{y}}\right)\right] \tag{2.12}$$

where $\bar{y}$, $\bar{\pi}$ and $\bar{R}$ are the steady state values of output, inflation, and the nominal interest rate, respectively. The term ρ represents the central banker's preference for interest rate smoothing. ϕ_π and ϕ_y are the weights on inflation and output gap assigned by the policy makers. Setting the parameter $\phi_y = 0$ implies strict inflation targeting regimes. I characterize core inflation as the inflation in the sticky price sector, $\pi_{s,t}$, and headline inflation as the overall inflation, π_t, for my policy experiments.

I also compute the optimal inflation target, which maximizes welfare conditional on a given choice of monetary rule and on the specific shocks hitting an economy. This target could have weights on different components (including imported goods) that are not necessarily the same as their weights in the CPI basket. I use a quasi-Newton algorithm to search over the parameters ρ_{π_s} and ρ_{π_f} for the following inflation target to maximize aggregate welfare:

$$\pi_t^* = \rho_{\pi_s}\pi_{s,t} + \rho_{\pi_f}\pi_{f,t} + (1-\rho_{\pi_s}-\rho_{\pi_f})\pi_{m,t} \tag{2.13}$$

In a model with no food sector, the second term would not appear; in a closed economy model, the third term would not appear. In such cases, the weights on the remaining two terms would have to sum to one.

2.3.5 Exogenous shock processes

I assume that productivity shocks in the food sector follow an AR(1) process. Firms in the sticky price sector face similar AR(1) productivity shocks but are also subject to mark-up shocks that reflect rent-seeking behavior that is typical in emerging market economies. This is a departure from models that only feature productivity shocks in the relevant sectors. Firms in the export sector face terms of trade shocks as they are price takers and face international market prices that are determined exogenously. This shock is similar to a productivity shock to the production of export goods. The structure of the export sector allows me to encompass the setup of Frankel (2008). To sum up, there are four shocks in the model with innovations to each of them drawn from i.i.d. normal distributions, namely the productivity shock in the food sector, the productivity shock in the sticky price goods sector, the markup shock in the sticky price goods sector, and the terms of trade shock in the nonfood export sector:

$$log\left(\frac{A_{f,t}}{\overline{A}_f}\right) = \rho_a^f log\left(\frac{A_{f,t-1}}{\overline{A}_f}\right) + \varepsilon_t^f, \quad \varepsilon_t^f \sim N(0, \sigma_a^f) \tag{2.14}$$

$$log\left(\frac{A_{s,t}}{\overline{A}_s}\right) = \rho_a^s log\left(\frac{A_{s,t-1}}{\overline{A}_s}\right) + \varepsilon_t^s, \quad \varepsilon_t^s \sim N(0, \sigma_a^s) \tag{2.15}$$

$$log\left(\frac{\tau_t}{\overline{\tau}}\right) = \rho_\tau log\left(\frac{\tau_{t-1}}{\overline{\tau}}\right) + \varepsilon_t^\tau, \quad \varepsilon_t^\tau \sim N(0, \sigma_\tau) \tag{2.16}$$

$$log\left(\frac{S_t}{\overline{S}}\right) = \rho_s log\left(\frac{S_{t-1}}{\overline{S}}\right) + \varepsilon_t^\sigma, \quad \varepsilon_t^\sigma \sim N(0, \sigma_s) \tag{2.17}$$

2.3.6 Welfare evaluations

My objective is to determine the policy rule that yields the highest level of lifetime utility as a weighted sum of households' welfare, which can be written as $V_{total} = \lambda V_t^f + (1-\lambda)V_t^n$. The second-order accurate consumer welfare measure is computed under different monetary policy regimes as in Schmitt-Grohé and Uribe (2004, 2007). Since the prior literature concludes that strict core inflation targeting is the welfare maximizing policy rule, that is used as the benchmark to evaluate the welfare gains (or losses) associated with alternative policy regimes. The parameter ω, the welfare gain from adopting an alternative policy rule, is defined as the fraction that has to be added to the strict core inflation targeting regime's (denoted by r) consumption process to yield a level of aggregate welfare equivalent to that under regime a. That is,

$$V_0^a = E_0 \sum_{t=0}^{\infty} \beta^t U((1+\omega)C_t^r, N_t^r) \tag{2.18}$$

A positive value of ω means that welfare is higher under the alternative policy rule. The welfare gain ω is given by

$$\omega = \left[\frac{V_0^a + D_0^r}{V_0^r + D_0^r}\right]^{\frac{1}{1-\sigma}} - 1 \tag{2.19}$$

where $D_0^r = E_0 \sum_{t=0}^{\infty} \beta^t \left[\phi_n \frac{(N_t^r)^{1+\psi}}{1+\psi}\right]$. A value of $\omega * 100 = 1$, represents a gain of one percentage point of permanent consumption under the alternative policy regime.

2.3.7 Parameter selection

Parameter selection for the model is a challenging task. There is no consensus on the values of some parameters and those used in the literature are mostly based on micro data from advanced countries. I pick baseline parameters from the existing literature and then do extensive sensitivity analysis with respect to the choice of key parameters.

The discount factor β equals 0.99, which amounts to an annual real interest rate of 4 percent. It is assumed that λ equals 0.4, implying that 40 percent of households in the economy are credit constrained, consistent with the data in Table 2.2. The baseline value of the risk aversion parameter $\sigma = 2$ is the value most commonly used in the literature on emerging market economies (Aguiar and Gopinath, 2007; Devereux, Lane, and Xu, 2006; García-Cicco, Pancrazi, and Uribe, 2010).

Following Basu and Fernald (1995) and Basu (1996), the parameter θ equals 11 (elasticity of substitution between the differentiated goods), implying a markup of 10 percent in the steady state. The probability that a price does not adjust in a given period (α) is set at 0.66 (Rotemberg and Woodford, 1997). This implies that prices remain fixed for a mean duration of 3 quarters, consistent with the microeconomic evidence for both emerging and advanced economies.[6] The appropriate value of the Frisch elasticity ($\frac{1}{\psi}$) is both important and controversial. For my benchmark case it is assumed to be 0.33 ($\psi = 3$). For the monetary policy parameters, I follow Galí, López-Salido, and Vallés (2004) and Mohanty and Klau (2005) and choose $\rho = 0.7$, $\phi_\pi = 2$, and $\phi_y = 0.5$.

An important feature of emerging countries is the high share of food expenditure in total household expenditures. To calibrate the subsistence level food consumption parameter C^* and the weight on food in the consumption index γ, it is assumed that the average expenditure on food is around 42 percent (consistent with household surveys in emerging countries). It is also assumed that on average one third of households' steady state food consumption is required for subsistence, enabling me to match estimates of the income elasticity of food consumption (about two-thirds).[7] As the demand for food is inelastic, I set $\eta = 0.6$ for the baseline case. Along with the subsistence level of food consumption, this implies a price elasticity of the demand for food of around -0.3 in the steady state, which is close to the USDA estimate.

[6]Evidence from Brazil (Gouvea, 2007), Chile (Medina, Rappoport, and Soto, 2007), Mexico (Gagnon, 2009), and South Africa (Creamer and Rankin, 2008) indicates that the frequency of price adjustment is much higher for food than for nonfood products and that price adjustments are less frequent during periods of low to moderate inflation. Since my model has no trend inflation and I impose price stickiness only in the nonfood sector, my parameter choice is consistent with the results of these studies.

[7]The income elasticity of food consumption is equal to one minus the subsistence ratio.

The major argument in favor of excluding food from the core price index is that the shocks to that sector are seasonal and transient. The value of the AR (1) coefficient of the food sector shock is set at 0.25 (implying that the shock has low persistence, which seems reasonable given the heavy dependence of agriculture on transitory weather conditions). Following the literature, the value of the AR(1) coefficient of the nonfood sector shock is set at 0.9 (Aguiar and Gopinath, 2007). The volatility of productivity shocks in emerging countries is higher than in advanced countries (Pallage and Robe, 2003; García-Cicco, Pancrazi, and Uribe, 2010). I set the standard deviation of the food productivity shock $\sigma_a^f = 0.03$ and the standard deviation of the nonfood productivity shock $\sigma_a^s = 0.02$. I follow Devereux, Lane, and Xu (2006) in calibrating the persistence and standard deviation of the terms of trade shock and choose $\rho_s = 0.77$ and $\sigma_s = 0.013$. I set the persistence of the mark-up shock $\rho_\tau = 0.9$ and the standard deviation parameter $\sigma_\tau = 0.01$.

2.4 Baseline Results

While it is not my objective to match specific moments, the incomplete markets version of my model more closely matches the properties of business cycle fluctuations in emerging economies relative to advanced economies. For instance, with the baseline parameters and shock processes, the incomplete markets model delivers inflation that is more volatile than in the complete markets model. This is consistent with the empirical findings of Fraga, Goldfajn, and Minella (2004),

Table 2.3: Parameter Values Used in Chapter 2

Parameter	*Definition*	*Value*
Structural		
λ	Share of households in the food sector (who are credit-constrained)	0.4
η	Elasticity of substitution between food and nonfood	0.6
C^*	Subsistence level of food consumption given subsistence ratio of 1/3	0.042
γ	Non-subsistence food consumption share	0.326
General		
β	Discount factor	0.99
σ	Risk aversion coefficient	2
θ	Elasticity of substitution between different varieties	11
ψ	Inverse of Frisch elasticity of labor supply	3
ψ_b	Interest rate elasticity of debt (for technical reasons only)	0.0007
α	Probability of not being able to reset price in each quarter	0.66
ξ	Elasticity of substitution between domestic and foreign goods	0.7
ζ	Share of imports in total nonfood consumption	0.3
Policy		
ρ	Degree of interest rate smoothing	0.7
ϕ_π	Degree of response to inflation	2
ϕ_y	Degree of response to output gap	0.5
Shocks		
ρ_a^f, σ_a^f	Productivity shocks in the food sector: persistence, std. dev.	0.25, 0.030
ρ_a^s, σ_a^s	Productivity shocks in the sticky price sector: persistence, std. dev.	0.90, 0.020
ρ_s, σ_s	Terms of trade shocks in the export sector: persistence, std. dev.	0.77, 0.013
ρ_τ, σ_τ	Markup shocks in the sticky price sector: persistence, std. dev.	0.90, 0.010

Bowdler and Malik (2005), and Pétursson (2008) that emerging economies have more volatile inflation than advanced ones.[8] In my model, the reason for this is

[8] Please refer to the appendix for more details.

that, due to lack of risk-sharing and consumption smoothing, the relative price between food and sticky price nonfood goods tends to be more volatile, rendering overall inflation also more volatile. Consumption is more volatile in the incomplete markets model, matching the findings of Aguiar and Gopinath (2007) and Kose, Prasad, and Terrones (2009) that consumption is more volatile in emerging economies than in advanced economies.

I now present the conditional welfare gains associated with different policy rules in my model. I include all four shocks–productivity shocks to two sectors, mark-up shocks, and terms of trade shocks–when conducting the welfare calculations discussed below.

Table 2.4 shows the welfare comparisons from targeting different price indices under complete and incomplete market settings, and also the sectoral weights for constructing the optimal price index in each case. With complete markets, the optimal price index puts the entire weight on the sticky price sector, with zero weights on food and traded goods, making it identical to core inflation targeting. Targeting headline inflation slightly reduces welfare. Thus, under complete markets, the choice of targeting strict core inflation is the best policy and dominates targeting of broader price indexes, as in Aoki (2001) and Benigno (2004).

However, with incomplete markets, this result no longer holds. The second row of Table 2.4 shows that headline inflation targeting is now welfare improving relative to core inflation targeting. Targeting the optimal price index yields a

Table 2.4: Welfare Comparisons under Different Inflation Targets

Scenario	*Welfare Gain*		*Weights in the Optimal Price Index*		
	Headline	*Optimal*	*Food Prices*	*Sticky Prices*	*Import Prices*
Complete markets	-0.09%	0.00%	0.00	1.00	0.00
Incomplete markets (baseline)	0.16%	0.20%	0.35	0.65	0.00
No food sector	-0.05%	0.00%	NA	1.00	0.00
No markup shocks	0.16%	0.20%	0.36	0.64	0.00
No food subsistence level	-0.07%	0.00%	0.08	0.92	0.00
Flexible headline vs core	0.12%	0.17%	0.34	0.66	0.00

Notes: The optimal price index comprises food prices, sticky nonfood domestic goods prices, and import prices. Welfare gains under alternative inflation targets are derived as permanent consumption gains relative to strict core inflation targeting. The third, fourth, and fifth rows show results when I introduce one deviation at a time from the baseline incomplete markets model. The last row compares flexible headline inflation targeting versus flexible core inflation targeting, where both rules include a positive weight on the output gap.

slightly higher welfare gain than targeting headline inflation.[9] The optimal price index assigns a weight of two-thirds to the sticky price sector and one-third to food prices. This result is a marked departure from the prior literature based on complete markets, wherein the optimal weight on food prices would be zero. On the other hand, it is consistent with the Benigno (2004) result (and, implicitly, the

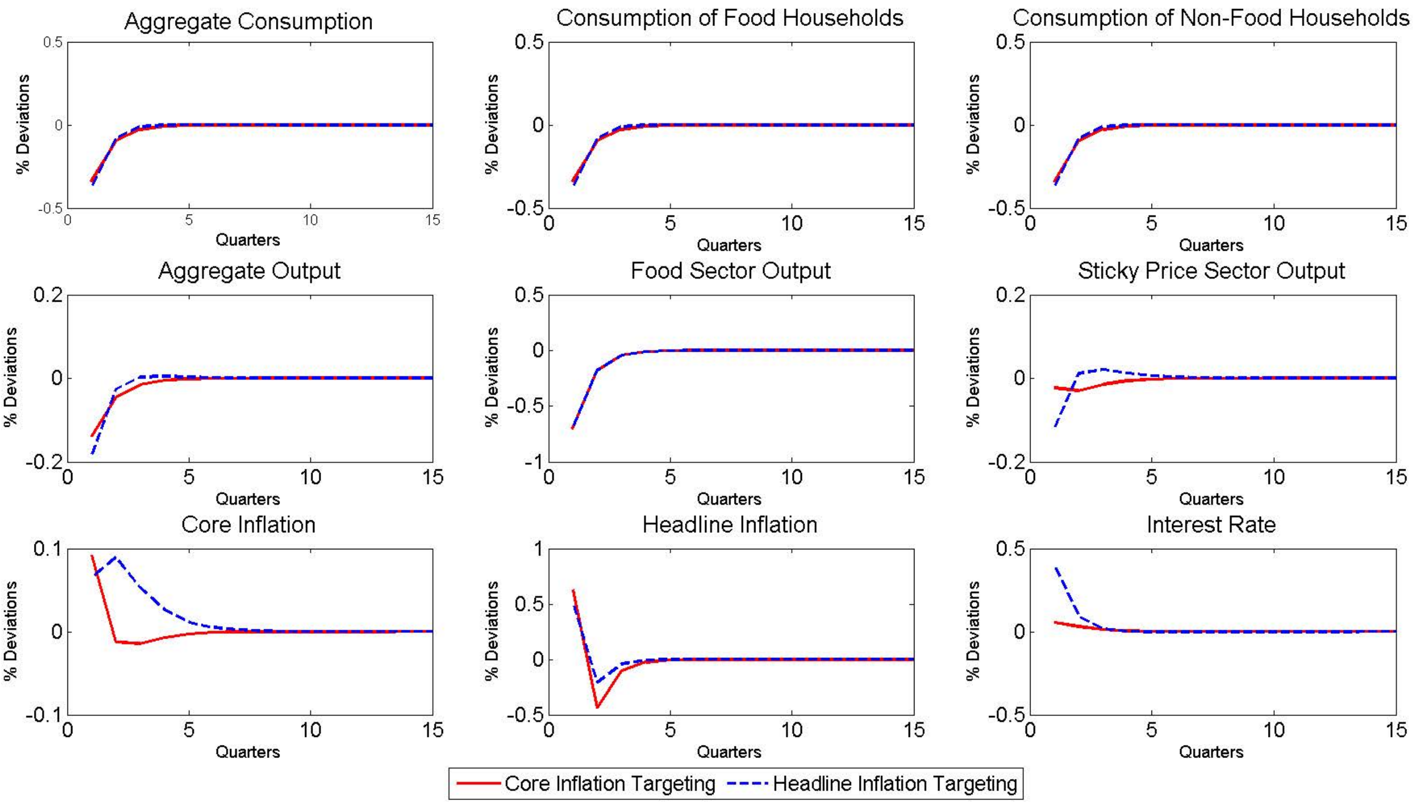
[9]The welfare gains are larger than those typically reported in models calibrated to advanced economy data. One reason is that emerging economies have more volatile output and consumption than advanced economies. Secondly, the financial frictions that I include in my model imply that monetary policy can have an even greater impact in terms of reducing the consumption volatility of different household types, which can in some cases be higher than aggregate consumption volatility.

results of Aoki, 2001, and Mankiw and Reis, 2003) that the weight on the traded goods sector is zero. That sector has flexible prices and agents in that sector have access to financial markets, so the classical result is confirmed.

To investigate these results more carefully, I analyze the responses of key variables to a food productivity shock because shocks to that sector highlight the relevance of market completeness. Figure 2.1 plots the impulse responses of various macroeconomic variables to a one percent negative food productivity shock under complete markets. Each variable's response is expressed as the percentage deviation from its steady state level. Impulse responses under a strict core inflation targeting rule are shown by the solid lines. The dashed lines are impulse responses under a strict headline inflation targeting rule. The strict headline inflation targeting regime results in a slightly higher volatility of consumption and output. Also, the policy response is more aggressive under strict headline inflation targeting, which leads to a further decline in output. These results are similar to those documented in the existing literature on inflation targeting.

Following an increase in inflation, the central bank raises interest rates, reducing aggregate demand (as consumers postpone their consumption following an increase in interest rates) and, thus, inflation. So, under complete markets, stabilizing core inflation is equivalent to stabilizing the output gap (Aoki, 2001) and there are no additional welfare gains from adopting headline inflation targeting. Thus, core inflation targeting is the welfare maximizing policy choice for the central bank.

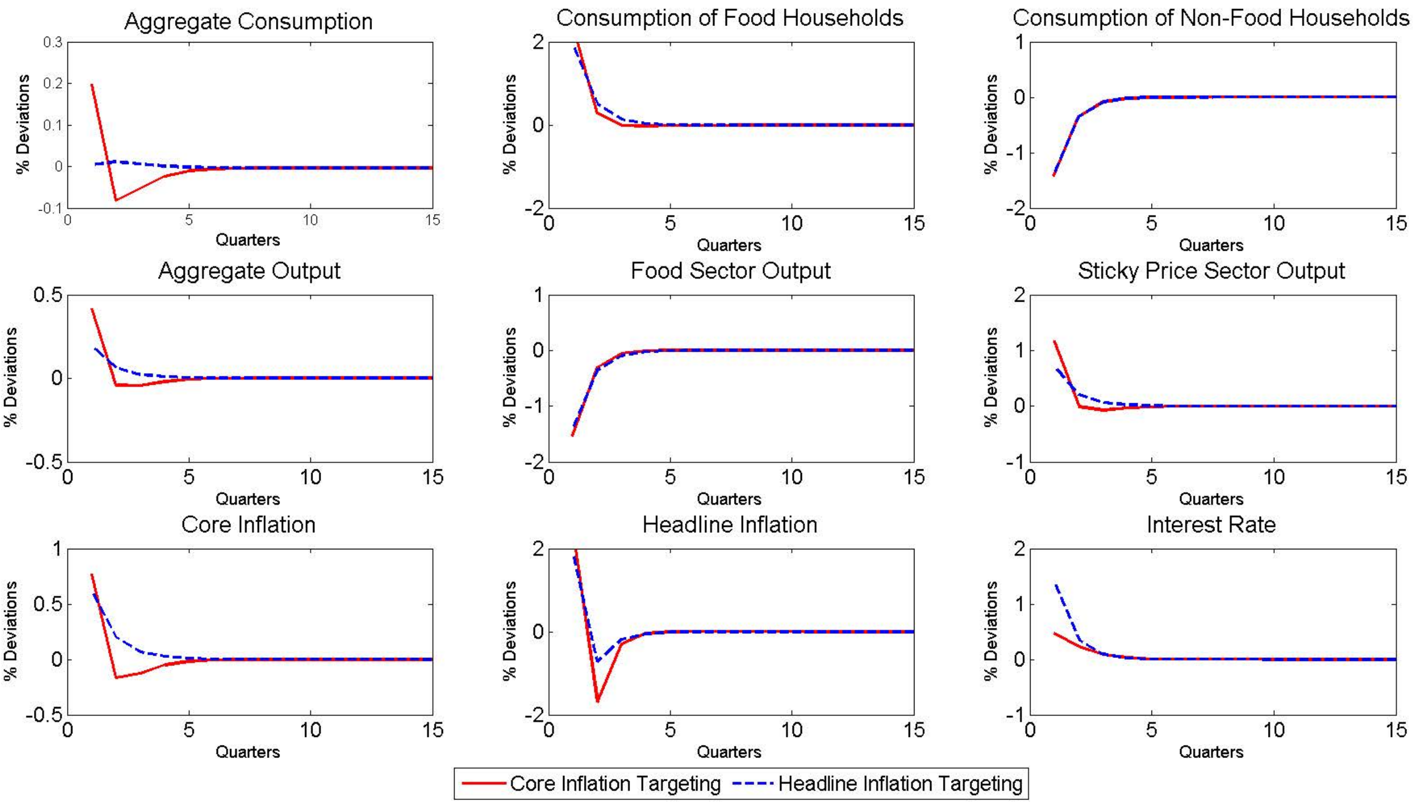
Figure 2.1: Impulse Responses to a Negative Food Productivity Shock (Complete Markets)



Notes: The impulse responses shown above are to a one percent negative shock to food productivity. Each variable's response is expressed as the percentage deviation from its steady state level.

However, in the presence of credit constrained consumers, headline inflation targeting appears to be a better policy choice. Figure 2.2 plots the impulse responses of various macroeconomic variables to a one percent negative food productivity shock under incomplete markets. Aggregate demand responds differently to monetary tightening under strict core inflation targeting and headline inflation targeting. The central bank is now able to effectively control aggregate

Figure 2.2: Impulse Responses to a Negative Food Productivity Shock (Incomplete Markets)



Notes: The impulse responses shown above are to a one percent negative shock to food productivity. Each variable's response is expressed as the percentage deviation from its steady state level.

demand by increasing interest rates only when it targets headline inflation. Aggregate demand, instead of going up slightly, goes up sharply in response to the shock if the central bank follows strict core inflation targeting. Thus, headline inflation targeting outperforms core inflation targeting as the former is more effective at stabilizing output.

In order to examine the mechanics behind this result, I look at the properties of aggregate demand under incomplete markets. In the presence of financial frictions, the consumption choices of different households vary (as opposed to complete markets, where the consumption choice of each household is identical). While the consumption demand of unconstrained households is responsive to interest rates (as they optimize intertemporally), the consumption demand of credit-constrained households is independent of interest rate changes and depends only on their current period wage income. Since only a fraction of aggregate demand is influenced by interest rate changes, a monetary tightening does not automatically mitigate the increase in aggregate demand. The response of aggregate demand crucially depends on the behavior of credit-constrained households.

Figure 2.2 shows that, following a negative shock to food productivity, the central bank raises the interest rate, lowering the demand of unconstrained households (as it is optimal for them to postpone consumption). However, it has no bearing on the demand of credit-constrained consumers. An increase in the relative price of food following a negative food productivity shock increases the wage income and, therefore, consumption demand of credit-constrained households. Thus, the demand of the two types of households moves in opposite directions following a negative shock to food productivity.

Which of the two demands dominates is determined by the policy regime. Under core inflation targeting, the increase in food prices (and, therefore, the wage income of food sector households) is higher than under headline inflation targeting. This higher wage income translates into higher consumption demand by credit-constrained consumers (who consume all of their current wage income), more than compensating for the lower consumption demand of unconstrained consumers. Consequently, aggregate demand rises. By contrast, when the central bank targets headline inflation, price increases in the food sector are lower and the rise in income and, therefore, the increase in consumption demand in that sector is smaller. Thus, monetary intervention is effective in achieving its objective of controlling aggregate demand only when the central bank targets headline inflation.

To formalize the above arguments, I examine the log-linearized aggregate demand equation, which is given by:[10]

$$\hat{c}_t = -\frac{(1-\lambda)\zeta_s}{\sigma} E_t(\hat{R}_t - \hat{\pi}_{t+1}) + E_t \hat{c}_{t+1} - \lambda \zeta_f E_t \Delta \hat{c}_{f,t+1} \tag{2.20}$$

where $\zeta_f = \frac{\bar{C}_f}{\bar{C}}$ is the steady state share of food sector households' consumption and $\zeta_s = \frac{\bar{C}_s}{\bar{C}}$ is the steady state share of nonfood sector households' consumption.

Furthermore, from the optimal labor supply of food sector households, I have:

$$\hat{c}_{f,t} = \frac{1+\frac{a}{\psi}}{1+\frac{a\sigma}{\psi}} \hat{x}_{f,t} + \frac{a(1+\frac{1}{\psi})}{1+\frac{a\sigma}{\psi}} \hat{A}_{f,t} \tag{2.21}$$

where $a = \frac{\bar{x}_f \bar{y}_x}{\bar{C}_f} > 1$.

[10] Aggregate demand is the sum of the log-linearized consumption demand of households in the two sectors. Variables with a hat denote log deviations from corresponding steady state values.

Equations (2.20) and (2.21) suggest that, in the presence of credit-constrained consumers, there is a link between aggregate demand and the relative price of food ($x_{f,t}$). In this setting, relative prices affect aggregate demand in addition to aggregate supply. Thus, the presence of financial frictions implies that managing aggregate demand requires the central bank to choose a policy regime that would limit the rise in wages of credit-constrained consumers (and, therefore, the increase in their demand).

I now present a series of variants of my benchmark model to investigate which features are quantitatively most important in driving the results. In the third row of Table 2.4, I consider a model without a food sector. The economy now has one sticky price sector while import prices are flexible. Core inflation targeting is now better than headline inflation targeting (which would have a positive weight on import prices), confirming the classical result of Aoki (2001). The optimal price index assigns a weight of zero to import prices, consistent with Benigno (2004) and indicating that openness of the economy is not crucial to the results.

In the fourth row of Table 2.4, I consider a variant of the baseline model with no markup shocks. When the economy is only hit by productivity and terms of trade shocks, it is still the case that the welfare gains from targeting headline inflation rather than core inflation are positive. The parameters in the optimal price index are also almost identical to those in the baseline case. Thus, unlike in the complete markets setting of Mankiw and Reis (2003), I find that markup shocks do not matter greatly in determining the right price index to target.

In the fifth row of Table 2.4, I evaluate the importance of the assumption of a subsistence level of food consumption. As noted earlier, this assumption affects the elasticity of substitution between food and nonfood goods. When I drop this assumption, targeting headline inflation leads to lower welfare than targeting core inflation. The intuition for this result is that, with perfect substitutability between food and nonfood, agents in the economy simply alter their consumption in response to a change in relative prices when there is a sector-specific productivity shock.

Thus, my main result is that the combination of incomplete financial markets and a subsistence level of food consumption, which are both characteristics relevant to emerging economies, makes it optimal for an inflation-targeting central bank to target headline rather than core inflation.

Next, I evaluate more practical monetary policy rules employed even by inflation targeting central banks, which typically include the output gap. The results in the last row of Table 2.4 show that flexible headline inflation targeting delivers better welfare outcomes than flexible core inflation targeting. This is true whether the price index in headline inflation targeting is based on CPI weights or the optimal price index. The weight on food, nonfood, and imported goods in the optimal price index is essentially the same as under strict headline inflation targeting.

2.5 Sensitivity Analysis and Extensions

In this section, I report results from a variety of experiments to test the robustness of my results to changes in the values of key parameters and certain aspects of the structure of the model. My results held up quite well to changes in values of most parameters, so in the discussion below I focus on the elements of my model that represent significant deviations from the prior literature. It should be noted that, since the steady state values of the models differ, it is only possible to make a comparison across regimes and not across different models.

2.5.1 Sensitivity to key parameters

One of the key parameter settings in the model is the proportion of households in the economy that are in the food sector and face credit constraints. As the share of households in this sector rises, welfare gains from headline inflation or optimal inflation targeting decline relative to core inflation targeting (see Table 2.5, Panel A). This might seem counter-intuitive as these households lack access to credit. The mechanism for this result is as follows. When the share of rural households is larger, under my parameter assumptions they will be poorer on average while the nonfood sector households will be richer. For a given drop in agricultural output, the relative price of food goes up by less when the consumption of food (above the subsistence level) by nonfood sector households is larger. When the share of rural households is small, the food consumption of households in the nonfood sector is also small in the steady state. Therefore, to accommodate a drop in food production, the relative price responds sharply.[11]

An important assumption in the model is the subsistence level of food. As noted earlier, this constraint does not bind in equilibrium but reduces the elasticity of substitution between food and nonfood goods. As shown in Table 2.4, when there is no subsistence level of food consumption, the weight of food in the optimal inflation target is small and core inflation targeting actually delivers higher welfare than headline inflation. As the subsistence level goes up, the weight of food in the optimal inflation index rises and core inflation targeting becomes inferior to headline inflation targeting (see Table 2.5, Panel B). Note that in my model the total share of food consumption is pinned down based on empirical estimates for emerging economies. A higher subsistence level of food therefore implies a lower level of nonsubsistence food consumption. Therefore, for any given amount of drop in the food output, market clearing necessitates a larger increase in the relative price of food. As a result, the higher is the subsistence level of food, the more volatile the impulse responses will be and the larger the welfare gain from headline inflation targeting.

An alternative approach to including a subsistence level of food in the utility function would be to directly pick a lower value for the elasticity of substitution between food and nonfood goods. Dropping the assumption that there is a

[11]Reducing the share of food sector households even further leads to implausibly large welfare gains, but this is because I have pinned down the average share of food expenditures in total household expenditures to be 0.42. Economies with small shares of rural households tend to be richer economies with substantially lower food shares in total expenditure.

Table 2.5: Sensitivity Tests

Parameter Value	*Welfare Gain*		*Weights in the Optimal Price Index*		
	Headline	*Optimal*	*Food Prices*	*Sticky Prices*	*Import Prices*
A. Share of Rural Households (baseline = 0.4)					
0.3	0.36%	0.49%	0.87	0.13	0.00
0.4	0.16%	0.20%	0.35	0.65	0.00
0.5	-0.02%	0.09%	0.22	0.78	0.00
0.6	-0.15%	0.04%	0.14	0.86	0.00
B. Subsistence Ratio of Food (baseline = 0.33)					
0.0	-0.07%	0.00%	0.08	0.92	0.00
0.1	-0.06%	0.01%	0.14	0.86	0.00
0.2	-0.03%	0.03%	0.21	0.79	0.00
0.3	0.08%	0.12%	0.31	0.69	0.00
0.4	0.56%	0.63%	0.48	0.52	0.00
C. Price Stickiness (baseline = 0.66)					
0.5	0.13%	0.16%	0.42	0.58	0.00
0.6	0.16%	0.19%	0.39	0.61	0.00
0.7	0.14%	0.19%	0.32	0.68	0.00
0.8	0.01%	0.11%	0.20	0.80	0.00
D. Financial Frictions (baseline = no access to domestic bonds)					
Full access to bonds	-0.08%	0.00%	0.01	0.99	0.00
Moderate frictions	0.02%	0.08%	0.24	0.76	0.00
Strong frictions	0.13%	0.17%	0.34	0.66	0.00

Notes: The optimal price index comprises food prices, sticky nonfood domestic goods prices, and import prices. Welfare gains under different parameter values are derived as permanent consumption gains relative to strict core inflation targeting.

subsistence level of food and lowering the elasticity to 0.38 yielded results similar to my baseline results. However, my approach is more realistic for emerging economies. Empirical evidence shows that the income elasticity of food consumption is smaller than one in emerging economies, which suggests it is more likely that food consumption is driven by the subsistence level.[12]

Another crucial parameter in the model is the share of food in total household consumption expenditures. When this share is small, the optimal inflation target puts most of the weight on the sticky price sector. Core inflation targeting then delivers higher welfare than headline inflation targeting, and the gains from targeting the optimal inflation index are modest. As the food share rises, the optimal inflation index involves an increasing weight on food prices. When food accounts for half of total consumption expenditures on average, the gains from headline inflation targeting become large and the optimal inflation index puts nearly the entire weight on food prices. This result appears at odds with one of the results in Mankiw and Reis (2003). They find that "the more important a price is in the consumer price index, the less weight that sector's price should receive in the stability price index." The incomplete markets structure of my model and the low elasticity of substitution between food and nonfood goods accounts for the difference between my result and theirs. However, my result that the weight on food prices is zero is true when markets are complete irrespective of the share of food in consumption expenditures, consistent with a different proposition in their paper–that

[12]See Anand and Prasad (2010) for more discussion. As noted earlier, the income elasticity of food consumption is equal to one minus the subsistence ratio so the model without subsistence level assumption cannot match the data for emerging countries.

sectors with more flexible prices should get a lower weight.

I also experimented with changing the degree of price rigidity in the sticky price sector (see Table 2.5, Panel C). Consistent with Mankiw and Reis (2003) and Benigno (2004), the weight of the sticky price sector in the optimal price index increases with the degree of price stickiness. As the degree of price stickiness increases, the optimal price index converges to core inflation, so the gains from either headline or optimal inflation targeting (relative to core inflation targeting) start to fall when prices are highly rigid.

2.5.2 Financial frictions

In the baseline model, it is assumed that food sector households face strong financial frictions, turning them into hand-to-mouth consumers. I now relax this assumption by introducing a portfolio holding cost for these households, enabling me to vary the extent of (common) financial frictions they face (see Table 2.5, Panel D). When the portfolio holding cost is zero, rural households have the same degree of access to the bond market as nonfood sector households. It is important to note that this is not equivalent to having complete financial markets. When the portfolio holding cost is very high, rural households hold zero bonds and the economy converges to the baseline incomplete markets case.

In the full access (but still not complete markets) scenario, food prices do enter with a nonzero weight in the optimal price index, although this weight is substantially smaller than in the baseline incomplete markets scenario. However, the welfare gain from targeting the optimal price index is small relative to core inflation targeting as the bonds give food sector households the ability to smooth consumption intertemporally although they cannot fully insure against sector-specific shocks. As the financial frictions become stronger, the welfare gains from headline inflation targeting rise and the share of food prices in the optimal price index also increases.

2.5.3 Common productivity shocks

Next, consider the case where there are only aggregate rather than sector-specific productivity shocks.[13] To this point, I have focused on the impact of a shock to productivity in the flexible price sector as it most clearly illustrates the point about what monetary policy rule is better in response to a shock to the flexible price part of the economy. Of course, while the impulse responses highlight different models' responses to only a food productivity shock, the simulation results include all shocks.

I recomputed the model with a productivity shock common to the food and the nonfood domestic goods sectors (and, as before, markup and terms of trade shocks as well). Intuitively, this should preserve the welfare gain from targeting inflation in the headline CPI or the optimal price index as there are no longer any

[13]Please refer to the appendix for more details of the results discussed in this subsection and the next one.

shocks specific to the rigid price sector. This is indeed what I find, confirming my main results. The results go through whether the common productivity shock is transitory (food sector shock) or more persistent (sticky price sector shock). Besides, food prices consistently have a significant weight in the optimal inflation target.

2.5.4 Fiscal policy interventions

Since incomplete financial markets are important for driving my results, an important question from a policy perspective is whether other policy tools could be used to promote risk-sharing, improve welfare outcomes, and alter the relative merits of headline versus core inflation targeting. One obvious candidate is a state-dependent redistribution between households in the food and nonfood sectors through the tax and transfer system.

Consider, for instance, a food tax whose revenues are distributed across all households in a lump sum fashion. A food tax would lead to a larger redistribution from food sector households to other households when the economy is hit by a shock that drives up the price of food. This would result in a smaller change in the relative price of food compared to my baseline model. I conducted some numerical experiments showing that, as the food tax increased (up to a certain level), the economy approached the complete markets benchmark, with smaller gains from headline inflation targeting relative to core inflation targeting.[14]

In short, in lieu of headline inflation targeting, fiscal policy interventions can be used to complete markets and improve welfare in an emerging market economy with incomplete financial markets and a subsistence level of food consumption. Targeting transfers in this fashion might be challenging for an emerging market economy, due to political economy constraints and governance problems. Nevertheless, I recognize that this is an important topic for future research.

2.6 Concluding Remarks

Previous research has concluded that optimal monetary policy should focus on offsetting nominal rigidities by stabilizing core inflation. However, those results rely on the assumption that markets are complete and that price stickiness is the only source of distortion in the economy. In this chapter, I have developed a more realistic model for emerging market economies that has the following key features–incomplete markets with credit-constrained consumers; households requiring a minimum subsistence level of food; low price elasticity of the demand for food; and a high share of expenditure on food in households' total consumption expenditure. I nest models such as those of Aoki (2001) and Benigno (2004)

[14] I get the symmetric result that food price subsidies can increase relative price volatility and improve the benefits from headline rather than core inflation targeting. The reason is that these subsidies would result in a net transfer from nonfood sector households to food sector households exactly when the relative price of food rises.

as special cases of my model.

I show that the classical result about the optimality of core inflation targeting can be overturned by introducing financial frictions. In the presence of credit-constrained consumers, targeting core inflation no longer maximizes welfare. Moreover, stabilizing inflation is not sufficient to stabilize output when markets are not complete. Under these conditions, headline inflation targeting improves welfare. My model also allows me to compute optimal price indexes that maximize welfare. The optimal price index includes a positive weight on food prices but, unlike headline inflation, generally assigns zero weight to import prices. This is because agents in that sector have access to financial markets and, unlike in the case of food, the price elasticity of the demand for goods produced in this sector is high.[15] A technical point to bear in mind is that, in the absence of aggregate homothetic preferences, it may no longer be optimal for monetary policy to target a particular price index. But my concern in this chapter is about a practical choice that inflation targeting central banks face, which is typically to target an aggregate price index.

One possible extension of my model is to include money explicitly. While this provides a saving mechanism for hand-to-mouth consumers, it would also strengthen the case for headline inflation targeting to preserve the value of monetary savings. Another extension would be to explore how fiscal policy tools,

[15] Looking beyond the CPI, Erceg, Henderson, and Levin (2000) find that in the presence of wage stickiness optimal monetary policy should target the nominal wage. Reinterpreting the sectors in the Mankiw-Reis (2003) model as including a labor sector with nominal wage rigidities yields similar results.

such as food price subsidies that affect the relative price of food as well as specific state-contingent redistributive mechanisms, could be used to improve welfare even with incomplete financial markets. In emerging market economies, such tools could be especially useful but are also more likely to be beset by problems in governance and implementation.

In future work, it will also be important to more explicitly consider the effects of particular inflation targeting rules on income distribution. For a normative analysis of optimal policies, distributional effects could be of first order importance in emerging market economies.[16] Another extension would be to include physical capital in the model. This highlights a practical dilemma that emerging market central banks often grapple with in pursuit of their objective of price stability. For instance, raising policy rates to deal with surging food price inflation can hurt industrial activity. While raising interest rates in response to a transitory negative shock to agricultural sector productivity might seem counter-intuitive, my results suggest that such a policy could in fact be welfare improving in an incomplete markets setting in which food consumption accounts for a large share of household consumption expenditures.

[16] See Prasad (2014) for a discussion.

CHAPTER 3

INTER-SECTORAL DISTRIBUTIONAL EFFECTS OF MONETARY POLICY IN EMERGING MARKET ECONOMIES

3.1 Introduction

The Balassa-Samuelson theory suggests that countries will experience real exchange rate appreciation when productivity growth in their tradable sectors is high. Since currency appreciation will hurt export competitiveness, central bankers in emerging market economies often attempt to limit nominal exchange rate appreciation. Some try to peg their currencies to the dollar, while many others adopt a policy of "leaning against the wind" to limit what they view as excessive exchange rate volatility. This happens when a central bank responds not only to inflation but also to nominal exchange rate fluctuations.

While many have tried to study monetary policy in the open economy setting, few have looked at the distributional consequences of different monetary policy rules. In this chapter, I focus on a specific contemporary policy issue mentioned above: nominal exchange rate management. I try to understand the distributional consequences when an emerging market central bank, motivated by concerns over export competitiveness, chooses to manage its nominal exchange rate and keeps it from appreciating.

This policy choice has significant distributional consequences, particularly on account of financial frictions and household heterogeneity in emerging market economies. Incomplete financial markets, coupled with insufficient access to formal financial institutions, limit households' ability to insure against household-specific or sector-specific shocks and magnify the distributional effects of aggregate macroeconomic fluctuations that may initially have only small effects.

Central banks use monetary policy to maintain export competitiveness when the interests of households in the tradable sector are given prominence–perhaps for political-economic reasons related to protecting jobs in that sector. A policy attempting to keep the nominal exchange rate stable can help stabilize relative prices and temporarily increase consumption by workers in this sector. However, this policy tends to be more inflation-tolerant and can have negative consequences for workers in the nontradable sector. It could even reduce aggregate welfare.

To analyze the distributional effects of such policy practices, I develop a theoretical model that allows me to simultaneously evaluate the aggregate and distributional effects of various monetary policy rules in a small open economy setting. The features that I incorporate into the model make it especially relevant for the analysis of monetary policy in emerging market economies. The main features include heterogeneous households, incomplete financial markets, and two sectors–tradable and nontradable goods. While tradable goods prices are set in international markets, nontradable goods prices are sticky.[1]

[1] Although my analysis focuses on middle-income emerging market economies, the features noted here and the results reported in the chapter apply equally, if not more forcefully, to low-income developing economies.

I find that nominal exchange rate management in response to positive productivity shocks in the tradable sector does indeed temporarily improve household consumption in that sector, which means that maintaining export competitiveness by monetary policy is feasible in the short run. This benefit comes, however, at the expense of lower consumption levels for households in the nontradable sector. Interestingly, I find that these effects are reversed under the welfare criterion. Nominal exchange rate management increases the volatility of household consumption in the tradable sector, thus reducing their welfare level. Moreover, when a central bank attempts to stabilize the nominal exchange rate in response to other shocks–such as productivity shocks in the nontraded goods sector or foreign interest rate shocks–the households in the tradable sector and the aggregate economy are negatively affected in terms of both temporary consumption losses and welfare levels.

Extended versions of the model enable me to consider the effects of various monetary policy rules against the background of a broader range of other policy settings. In the presence of capital controls, exchange rate management can deliver even sharper temporary consumption benefits to households in the tradable sector relative to inflation targeting, given positive productivity shocks in the tradable sector. But welfare costs for these households also rise on account of higher consumption volatility. Flexible inflation targeting, which incorporates a measure of the output gap in the monetary policy rule, leads to similar results. I also find that fiscal policy, through a set of targeted taxes and transfers, can more efficiently achieve similar distributional effects that are similar to those under exchange rate management.

3.1.1 Related literature

My work builds on three existing strands of research: models of the distributional effects of monetary policy and heterogeneous agent, the new open economy macroeconomics, and macroeconomics models for emerging market economies.

Interest in the distributional effects of monetary policy has been revived by a handful of important new papers. In an early contribution, Romer and Romer (1999) document that inflation and macroeconomic instability are correlated with increases in inequality. In a recent paper, Doepke, Schneider, and Selezneva (2015) analyze the channels through which inflation affects distribution. Meanwhile, Brunnermeier and Sannikov (2012) tackle the issue from the aspect of financial institutions and show how monetary policy has distributional effects by affecting interest rates and the yield curve.

To study distributional effects, it is important to include heterogeneity across households in my model. One approach is to introduce idiosyncratic labor income shocks as in Krusell and Smith (1998). However, given the focus of this chapter, I favor an alternative approach to modeling heterogeneity that divides households into a few groups. For example, the differentiating factor can be the assumption of differential access to financial markets, as in Galí, López-Salido, and Vallés (2004). Other papers using a similar framework include Bilbiie (2008).

The strand of literature discussed above focuses mainly on closed economies in theoretical work and on the U.S. and other advanced economies in empirical work. My contribution is to extend this work to a small open economy setting that is relevant to emerging markets and to assess both the distributional and aggregate effects of various monetary policies in such economies.

The new open economy macroeconomics literature serves as my modeling foundation. Recent examples of the dynamic stochastic general equilibrium (DSGE) framework I employ in this chapter can be found in Clarida, Galí, and Gertler (2002).[2] In particular, I adapt the modeling framework of Galí and Monacelli (2005, 2008), who develop a small open economy model with nominal rigidities. Engel (2011) shows that optimal policy targets CPI inflation, the output gap, and currency misalignment. The instrument rule derived in that setup does not include either the output gap or the measure of currency misalignment. In a small open economy setting, Kollmann (2002) and Leitemo and Söderström (2005) conclude that there is no welfare gain from augmenting the monetary policy reaction function with an exchange rate variable. However, there is considerable evidence that, in practice, emerging markets do incorporate exchange rate considerations in their monetary policy formulations. For instance, Mohanty and Klau (2005) find that, in most emerging market economies, the interest rate responds strongly to the exchange rate. Frömmel, Garabedian, and Schobert (2011) document that central banks in Eastern Europe respond to exchange rate fluctuations. The same re-

[2]Other important early papers in the literature on which I build include Benigno and Benigno (2003), Devereux and Engel (2003), Benigno (2004), Corsetti and Pesenti (2005), and Sutherland (2005).

sult holds even for advanced but highly open economies. Lubik and Schorfheide (2007) conclude, for example, that the Bank of Canada and the Bank of England take account of the nominal exchange rate in their policy reactions.

Another important strand within the new open economy macroeconomics literature is work on emerging market economies. For instance, Aguiar and Gopinath (2007) suggest that emerging market economies face large nonstationary productivity shocks so that growth trend fluctuations constitute their business cycles. García-Cicco, Pancrazi, and Uribe (2010) use a small open economy with financial frictions to characterize business cycles in emerging markets. Devereux, Lane, and Xu (2006) compare alternative monetary policies with high and low exchange rate pass-through. Liu and Spiegel (2015) study optimal monetary policy and capital account restrictions in a small open economy.

Both of these strands of the existing literature on open economies have tended to focus on aggregate welfare effects rather than distributional consequences. My contribution relative to this literature is to study distributional effects rather than only aggregate welfare consequences of monetary policy. This highlights a key point of departure of my modeling framework compared with above-cited studies–the presence of financial frictions. Financial market incompleteness is crucial for generating distributional effects. Interaction between nominal rigidities and financial frictions plays a key role in my modeling framework.[3]

[3] In recent work that is related to ours, Anand, Prasad, and Zhang (2015) develop a DSGE model that features a food sector and incomplete financial markets to determine the measure of inflation a developing economy central bank should target.

3.2 Exchange Rate Dynamics in Periods of High Tradable-sector Growth

Fast-growing emerging market economies often encounter appreciation pressure on their currencies. The traditional Balassa-Samuelson theory suggests that countries will experience real exchange rate appreciation when productivity growth in their tradable sectors is high. As a result, emerging market economies with booming export sectors will gradually lose their competitiveness due to currency appreciation, which is undesirable in the eyes of policy makers.

Naturally, policy makers would like to slow currency appreciation to maintain export competitiveness. There has been plenty of anecdotal evidence suggesting that emerging market economies actively manage their exchange rates. The implementation can take any of several forms, ranging from hard pegs to an inflation-targeting monetary policy regime that also responds to exchange rate fluctuations. The question is whether I have empirical evidence demonstrating that emerging market economies indeed try to keep their currencies from appreciating in periods of high tradable-sector growth.

In this section, I construct a cross-country dataset to formally assess this argument. I retrieve data on industrial production, official exchange rates, and inflation rates from 53 developing countries dating to 1970. The data source is the International Financial Statistics database maintained by the International Monetary Fund. I use industrial production growth to proxy tradable-sector growth. I construct the CPI-based bilateral real exchange rate between a developing country and the United States to capture changes in real exchange rates. There are two reasons I prefer this bilateral real exchange rate. First, data on real effective exchange rates have been unavailable for many developing countries until very recently. Second, the bilateral exchange rate with the United States is often the most important one for many developing countries.

Finally, I need to identify periods of high tradable-sector growth to analyze the movement of nominal and real exchange rates. I borrow the concept of growth accelerations from Hausmann, Pritchett, and Rodrik (2005). In their original paper, they study periods in which GDP growth is high in absolute terms and higher than the historical average, and define those periods as episodes of growth acceleration. I apply their criteria to growth in industrial production, a proxy for tradable-sector growth.

There are two major criteria for selecting episodes of high tradable-sector growth:

1. *The average growth in industrial production is higher than $\bar{g}$ for K periods, namely $g^{IP}_{t,t+K} > \bar{g}$.*
2. *The difference between the K-period growth rate and the historical average is larger than $\tilde{g}$, namely $g^{IP}_{t,t+K} - g^{IP}_{1,t-1} > \tilde{g}$.*

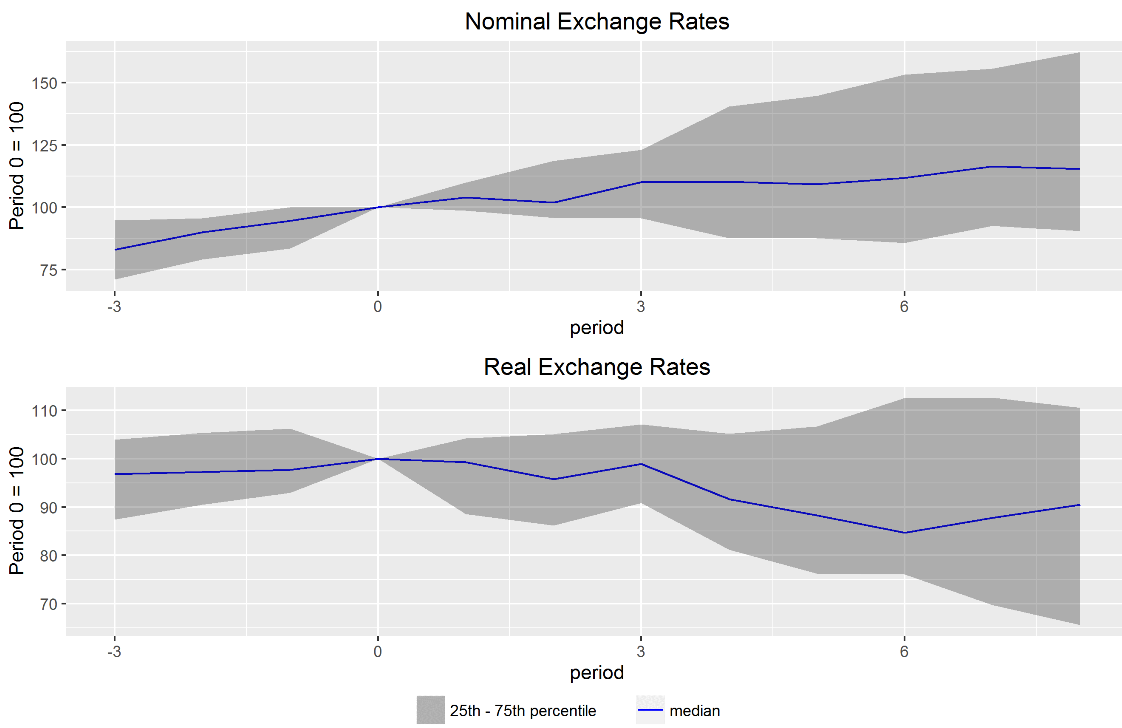
I borrow the parameter values used in Hausmann, Pritchett, and Rodrik (2005) and set $\bar{g} = 3.5\%$, $\tilde{g} = 2\%$, and $K = 8$. In addition, I impose two additional requirements to avoid over-counting episodes. First, the economy must be growing above the historical maximum level, which excludes recovery periods after crises. Second, the start year of an episode must be at least three years away from the start year of another episode, which minimizes the chance of double-counting one long episode multiple times. In total, I find 41 episodes of high tradable-sector growth.

At last, I set the year that immediately precedes the high-growth episode as period 0 and normalize the nominal and real exchange rates in period 0 as 100. I then transform exchange rates in other periods against the period-0 values such that values higher than 100 mean depreciation against the period-0 exchange rate. I compute the median paths of nominal and real exchange rates across countries as well as the area of realizations between the 25th percentile and the 75th percentile. The results are summarized in Figure 3.1.

The two charts in Figure 3.1 indicate that, in periods of high tradable-sector growth, nominal exchange rates remain fairly stable and even slightly depreciate against the period-0 level. On the contrary, real exchange rates remain flat for the first two years and start to appreciate sharply in the following years. This result suggests that emerging market economies are indeed reluctant to allow their currencies to appreciate. However, even without nominal appreciation, the real exchange rate appreciation predicted by the Balassa-Samuelson theory will ultimately happen when domestic inflation picks up.

In conclusion, emerging market central banks can use monetary policy to prevent nominal appreciation and maintain export competitiveness in the short run;

Figure 3.1: Exchange Rate Dynamics in Periods of High Tradable-sector Growth



Notes: This figure shows the dynamics of nominal and real exchange rates in periods of high tradable-sector growth across countries. The solid blue lines are the median paths of nominal and real exchange rates relative to period 0. The period-0 exchange rates are normalized to 100, and values higher than 100 mean depreciation against the period-0 exchange rate. The grey area represents the paths of exchange rates between the 25th percentile and the 75th percentile. The two charts indicate that, in periods of high tradable-sector growth, nominal exchange rates remain fairly stable but real exchange rates appreciate sharply.

however, real appreciation will occur gradually due to rising domestic inflation. Recognizing that an emerging market central bank, motivated by concerns over export competitiveness, is likely to use monetary policy to stabilize nominal exchange rates, it is natural to explore the aggregate and distributional effects, which I will do in the next few sections.

3.3 Model

In this section, I develop a small open economy model with features that are relevant to emerging market economies and use it to study the distributional effects of nominal exchange rate management. I sketch the main features of the model here, deferring a more detailed description of the model and derivations of key equations to the appendix.

3.3.1 Households

The economy is inhabited by a continuum of infinitely lived households. There are two types of households: (i) measure $\lambda > 0$ of households work in the tradable sector, and (ii) measure $1 - \lambda$ of households work in the nontradable sector. Prices of tradable goods are flexible and set in the foreign currency, determined in international markets, and taken as given from the home economy's point of view. Prices of nontradable goods are set by monopolistically competitive firms, denominated in the domestic currency, and sticky.

I assume that labor is immobile across the tradable and nontradable sectors.[4] The representative household is denoted by the superscript i, and indexed by T

[4] This assumption reflects the large inter-sectoral wage differentials in emerging market economies. Artuç, Lederman, and Porto (2013) present estimates of labor mobility costs in developing countries and document that the costs of adjustment to trade shocks are high in these economies, restricting inter-sectoral labor mobility. Lee and Wolpin (2006) find that, even in advanced economies, there are large costs for labor to move across sectors.

(tradable sector) and N (nontradable sector) respectively. Household i maximizes the discounted stream of utility:

$$\max E_0 \sum_{t=0}^{\infty} \beta^t [U(C_t^i, L_t^i)] \tag{3.1}$$

where $\beta \in (0, 1)$ is the discount factor, C_t^i is the composite consumption index of household i in period t, including tradable and nontradable goods, and L_t^i is the labor supplied by household i. The utility function takes the form:

$$U(C_t^i, L_t^i) = \frac{{C_t^i}^{1-\sigma}}{1-\sigma} - \phi_i \frac{{L_t^i}^{1+\psi}}{1+\psi}, \quad i \in \{T, N\} \tag{3.2}$$

where σ is the risk-aversion coefficient, the parameter ψ is the inverse of the Frisch elasticity, and ϕ_i is the scaling factor. The consumption index is defined as

$$C_t^i = \left[b^{\frac{1}{\xi}} \left(C_{T,t}^i \right)^{\frac{\xi-1}{\xi}} + (1-b)^{\frac{1}{\xi}} \left(C_{N,t}^i \right)^{\frac{\xi-1}{\xi}} \right]^{\frac{\xi}{\xi-1}} \tag{3.3}$$

where $C_{T,t}^i$ represents tradable goods and $C_{N,t}^i$ represents nontradable goods. The elasticity of substitution between tradable and nontradable goods is given by $\xi \in (0, +\infty)$ and $b \in (0, 1)$ is the weight on tradable goods in the consumption index. The composite tradable good $C_{T,t}^i$ comprises both domestically produced and imported tradable goods ($C_{H,t}^i$ and $C_{F,t}^i$,respectively) and is given by

$$C_{T,t}^i = \left[a^{\frac{1}{\eta}} \left(C_{H,t}^i \right)^{\frac{\eta-1}{\eta}} + (1-a)^{\frac{1}{\eta}} (C_{F,t}^i)^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}} \tag{3.4}$$

The parameter $a \in (0, 1)$ denotes the share of domestically produced goods in the tradable goods consumption index, and $\eta \in (0, +\infty)$ is the elasticity of substitution between domestically produced and imported tradable goods. The composite nontradable good $C^i_{N,t}$ is a continuum of differentiated goods, given by

$$C^i_{N,t} = \left[\int_0^1 C^i_{N,t}(j)^{\frac{\varepsilon-1}{\varepsilon}} dj \right]^{\frac{\varepsilon}{\varepsilon-1}} \tag{3.5}$$

The parameter $\varepsilon > 1$ represents the elasticity of substitution between any two differentiated nontradable goods.

3.3.2 Budget constraints and financial markets

This section characterizes financial frictions that households face, distinguishing this chapter from previous research. With complete financial markets, heterogeneous households can share risk arising from sector-specific shocks (or shocks that have asymmetric effects across sectors), implying that monetary policy has no distributional consequences. This assumption is unrealistic in the context of emerging market economies, where financial frictions are pervasive and a large share of households do not have access to formal financial markets.[5]

Since most of these households work in the informal sector that produces

[5] Demirgüç-Kunt and Klapper (2012) find that a majority of households in most emerging market economies lacks access to the formal financial system. By contrast, in advanced economies nearly all households have such access.

mainly nontradable goods, I assume that households working in this sector lack access to financial markets and simply consume their wage income in each period. So these households are akin to "rule of thumb" consumers.[6] A representative household in the nontradable sector maximizes its lifetime utility, given by equation (3.1), subject to the budget constraint:

$$P_t C_t^N = W_{N,t} L_t^N + \Pi_{N,t} \tag{3.6}$$

where the right hand side is the total value of output in the nontradable goods sector. $W_{N,t}$ is the nominal wage in the nontradable goods sector and $\Pi_{N,t}$ represents profits earned by firms in this sector. The total expenditure needed to attain a consumption index C_t^N is given by $P_t C_t^N$ where P_t is defined as

$$P_t = \left[b P_{T,t}^{1-\xi} + (1-b) P_{N,t}^{1-\xi} \right]^{\frac{1}{1-\xi}} \tag{3.7}$$

$P_{T,t}$ denotes the price of tradable goods and is given by

$$P_{T,t} = \left[a P_{H,t}^{1-\eta} + (1-a) P_{F,t}^{1-\eta} \right]^{\frac{1}{1-\eta}} \tag{3.8}$$

$P_{N,t}$, the price index of nontradable goods, is defined as

[6]As discussed below, there is no physical capital in the model and also no alternative storage technology that would allow for intertemporal consumption smoothing by households that have no access to financial markets.

$$P_{N,t} = \left[\int_0^1 P_{N,t}(j)^{1-\varepsilon} dj \right]^{\frac{1}{1-\varepsilon}} \tag{3.9}$$

Households in the tradable goods sector receive labor income and can buy one-period nominal bonds and foreign bonds to smooth their consumption. A representative household in this sector maximizes lifetime utility, given by equation (3.1), subject to the following budget constraint

$$P_t C_t^T + B_t + e_t B_t^* + \frac{\psi_B}{2} B_t^{*2} \leq W_{T,t} L_t^T + R_{t-1} B_{t-1} + e_t R_{t-1}^* B_{t-1}^* \tag{3.10}$$

where B_t and B_t^* represents the quantity of one-period nominal risk-free discount bonds denominated in domestic and foreign currencies, respectively. The nominal exchange rate is denoted by e_t and the gross nominal interest rates for the two types of bonds are denoted by R_t and R_t^*, respectively.[7] $W_{T,t}$ is the nominal wage in the tradable goods sector and L_t^T is the labor supply in this sector.

3.3.3 Production

Firms in the tradable goods sector use a linear technology in labor $Y_{H,t} = A_{H,t} L_t^T$, subject to a common productivity shock $A_{H,t}$. Firms in this sector are price takers. Import prices are exogenous and follow the law of one price. The terms of trade, which links import and export prices, determines the export price. Thus, $P_{H,t} =$

[7] I also include a small quadratic portfolio holding cost for foreign bond holdings, as suggested by Schmitt-Grohé and Uribe (2003), only to induce stationarity.

$S_t P_{F,t}$, where S_t is the terms of trade. The zero profit condition then determines labor demand and wages.

Similarly, firms in the nontradable goods sector use a linear technology in labor $Y_{N,t}(j) = A_{N,t} L_t^N(j)$ and are subject to a common productivity shock $A_{N,t}$. Following Calvo (1983), I assume that a fraction $\theta \in (0, 1)$ of firms cannot change their price in each period. The remaining firms choose the optimal reset price to maximize their discounted future profits:

$$\max_{P_{N,t}(j)} E_t \sum_{s=0}^{\infty} \left\{ (\beta\theta)^s \left(\frac{C_{t+s}^{N\ -\sigma}}{P_{t+s}} \right) [P_{N,t}(j) - MC_{N,t+s}]\, Y_{N,t+s}(j) \right\} \tag{3.11}$$

where MC denotes the marginal cost of production in nominal terms.

3.3.4 Monetary policy

I define aggregate inflation as $\pi_t = P_t / P_{t-1}$, inflation in the nontradable goods sector as $\pi_{N,t} = P_{N,t}/P_{N,t-1}$, and tradable goods sector inflation as $\pi_{T,t} = P_{T,t}/P_{T,t-1}$. The steady state is characterized by constant prices (zero inflation) and no price stickiness in the economy.

The central bank sets the short-term nominal interest rate R_t according to a simple inflation-targeting rule, with a possible additional response to exchange rate fluctuations (see, e.g., Lubik and Schorfheide, 2007):

$$log\left(\frac{R_t}{\bar{R}}\right) = \rho\ log\left(\frac{R_{t-1}}{\bar{R}}\right) + (1-\rho)\left[\phi_\pi log\left(\frac{\pi_t}{\bar{\pi}}\right) + \phi_e log\left(\frac{e_t}{e_{t-1}}\right)\right] \tag{3.12}$$

where $\bar{\pi}$ and $\bar{R}$ are the steady state values of inflation and the nominal interest rate, respectively. The term ρ represents the central banker's preference for interest rate smoothing.[8] ϕ_π and ϕ_e are the weights assigned by the central banker to the deviations of inflation from its steady state level and to the fluctuations of the nominal exchange rate.[9] Setting the parameter ϕ_e to zero implies a pure inflation targeting regime, wherein the central banker is not concerned about the level of the exchange rate except insofar as it affects inflation. I set inflation targeting as the benchmark rule and then conduct policy experiments to study the distributional effects of alternative monetary policy rules that place varying weights on the exchange rate.

[8]Interest rate smoothing behavior by central banks and its benefits are well documented (Clarida, Galí, and Gertler, 1998). Mohanty and Klau (2005) find that emerging market central banks also place substantial weight on interest rate smoothing. The formulation of the monetary policy rule with interest rate smoothing is similar to that used by Clarida, Galí, and Gertler (1999).

[9]Technically, one could also formulate a policy rule that includes the deviation of the exchange rate from its steady-state level rather than changes in the level of the exchange rate. However, this would be harder to interpret and operationalize in an environment where nominal and real shocks can continuously affect the steady-state level of the nominal exchange rate. The formulation in equation (3.12) is in line with the stated objective of many emerging market central banks that describe such policies as "leaning against the wind" to limit sharp short-run exchange rate volatility. In any event, the results were qualitatively similar when I used deviations of the nominal exchange rate from its steady-state level in the policy rule.

3.3.5 Exogenous shock process

I assume that productivity shocks in the tradable and nontradable goods sectors follow AR(1) processes. Firms in the export sector are subject to terms of trade shocks as they are price takers and face international market prices that are determined exogenously. The small open economy may also face foreign interest rate shocks. To sum up, there are four shocks in the model, with innovations to each of them drawn from *i.i.d.* normal distributions:

$$
\begin{array}{lrcll}
\text{Productivity shock, tradable goods:} & log\left(\frac{A_{H,t}}{\bar{A}_H}\right) & = & \rho_a^H log\left(\frac{A_{H,t-1}}{\bar{A}_H}\right) + \varepsilon_t^H, & \varepsilon_t^H \sim N(0, \sigma_a^H) \\
\text{Productivity shock, nontradable goods:} & log\left(\frac{A_{N,t}}{\bar{A}_N}\right) & = & \rho_a^N log\left(\frac{A_{N,t-1}}{\bar{A}_N}\right) + \varepsilon_t^N, & \varepsilon_t^N \sim N(0, \sigma_a^N) \\
\text{Terms of trade shock, exports:} & log\left(\frac{S_t}{\bar{S}}\right) & = & \rho_s log\left(\frac{S_{t-1}}{\bar{S}}\right) + \varepsilon_t{}^\sigma, & \varepsilon_t^\sigma \sim N(0, \sigma_s) \\
\text{Foreign interest rate shock:} & log\left(\frac{R_t^*}{\bar{R}^*}\right) & = & \rho_r log\left(\frac{R_{t-1}^*}{\bar{R}^*}\right) + \varepsilon_t{}^r, & \varepsilon_t^r \sim N(0, \sigma_r)
\end{array}
$$

In the baseline model, I focus on productivity shocks in the tradable sector as that is central to the questions posed in this chapter and the exact reason why emerging market central banks want to manage the nominal exchange rate.

3.3.6 Policy evaluation

Given my objective of determining the distributional effects of various monetary policy rules, I need suitable metrics to evaluate both the temporary consumption effects and welfare effects of specific policy choices in response to particular sources of shocks.[10]

By temporary consumption effects, I mean the temporary effect of nominal exchange rate management on consumption when positive productivity shocks hit the tradable sector. Nominal exchange rate management is desirable if it can temporarily boost consumption in periods of high tradable-sector growth. To quantify temporary consumption effects, I rely on impulse response functions. For instance, given a one-standard-deviation positive productivity shock in the tradable sector, I calculate the accumulated consumption gains or losses under nominal exchange rate management against the benchmark policy, for a specific type of household for a sufficiently long period of time T. In other words, the cumulative difference between the two impulse responses represents the temporary effects of various monetary policy rules on household consumption.

To measure welfare effects of nominal exchange rate management, I compare welfare levels of a representative household in a given sector under alternative policy rules relative to the baseline rule. The welfare effects of alternative monetary policy rules can be quite different from their temporary consumption effects because the former involve an evaluation of unconditional welfare in an economy facing continuous symmetric productivity shocks. In other words, a central bank committed to nominal exchange rate stability will prevent exchange rates from fluctuating, which may increase consumption in good times but reduce consump-

[10] I use temporary consumption gains as a measure of distributional effects and the desirability of a certain policy in the short run because many governments in emerging market economies consider raising the living standard of their citizens as their primary goal, which is best captured by consumption.

tion in bad times.

I compute the second-order accurate consumer welfare measure under various monetary policy regimes as in Schmitt-Grohé and Uribe (2004, 2007). Household welfare in the tradable goods sector is denoted by V_t^T and that of households in the nontradable goods sector is denoted by V_t^N. Aggregate welfare in the economy is defined as the population-weighted sum of the welfare of the two types of households: $V_{total} = \lambda V_t^T + (1-\lambda)V_t^N$. I define ω, the welfare gain from adopting an alternative policy rule, as the fraction that has to be added to the inflation-targeting regime's (where the regime is denoted by r) consumption process to yield a level of aggregate welfare equivalent to that under regime a. That is,

$$V_0^a = E_0 \sum_{t=0}^{\infty} \beta^t U((1+\omega)C_t^r, N_t^r) \tag{3.13}$$

A positive value of ω means that welfare is higher under the alternative policy rule. The welfare gain ω is given by

$$\omega = \left[\frac{V_0^a + D_0^r}{V_0^r + D_0^r}\right]^{\frac{1}{1-\sigma}} - 1 \tag{3.14}$$

where $D_0^r = E_0 \sum_{t=0}^{\infty} \beta^t [\phi_n \frac{(N_t^r)^{1+\psi}}{1+\psi}]$. A value of $\omega * 100 = 1$, represents a gain of one percentage point in permanent consumption under the alternative policy rule relative to the baseline.

3.3.7 Parameter selection

Given limited research on macroeconomic models for emerging market economies, there is no consensus on the values of some parameters and many parameter values are borrowed from micro data from advanced countries. Nonetheless, I try to find the most reasonable parameter values and implement sensitivity analysis with respect to the choice of key parameters to check the robustness of my results. The values of the key model parameters are summarized in Table 3.1. The time period in my model is equivalent to a quarter and I pick parameters corresponding to this frequency.

I choose $\beta = 0.99$, which is equivalent to an annual real interest rate of 4 percent. I use $\sigma = 2$ as the baseline value of the risk-aversion parameter, a value commonly used in the literature on emerging market economies (Aguiar and Gopinath, 2007; Devereux, Lane, and Xu, 2006; García-Cicco, Pancrazi, and Uribe, 2010). The share of domestically produced tradable goods, denoted by a, is set at 0.7. This implies that, in the steady state, 70 percent of all tradable goods consumed in the home country are produced domestically. The consumption weight of tradable goods b is set at 0.6. The value chosen for a is common in the open economy literature (Obstfeld and Rogoff, 2001) and I use the combined shares of the agricultural and manufacturing sectors in emerging market economies to approximate b. I set the probability that a price in the nontradable sector remains fixed in a given period (θ) at 0.66 (Rotemberg and Woodford, 1997). This implies that prices in that sector do not adjust for a mean duration of 3 quarters.

Table 3.1: Parameter Values Used in Chapter 3

Parameter	*Definition*	*Value*
β	Discount factor	0.99
σ	Risk-aversion coefficient	2
λ	Share of households working in the tradable goods sector	0.6
a	Share of domestically produced tradable goods in total tradable goods	0.7
b	Share of tradable goods in total output	0.6
ε	Elasticity of substitution between different varieties	11
η	Elasticity of substitution between domestic and foreign tradable goods	2
ξ	Elasticity of substitution between tradable and nontradable goods	0.6
ψ	Inverse of Frisch elasticity of labor supply	1.5
ψ_b	Interest rate elasticity of debt (for technical reasons only)	0.0007
θ	Probability of not being able to reset price in a given quarter	0.66
Policy Parameters (baseline)		
ρ	Degree of interest rate smoothing	0.75
ϕ_π	Degree of response to inflation	1.5
ϕ_y	Degree of response to nominal exchange rate	0.5
Shock Parameters		
ρ_a^H, σ_a^H	Productivity shocks in the tradable goods sector: persistence, std. dev.	0.90, 0.020
ρ_a^N, σ_a^N	Productivity shocks in the nontradable goods sector: persistence, std. dev.	0.90, 0.015
ρ_s, σ_s	Terms of trade shocks in the tradable goods sector: persistence, std. dev.	0.47, 0.047
ρ_r, σ_r	Foreign interest rate shocks: persistence, std. dev.	0.46, 0.012

Notes: A period in the model corresponds to one quarter.

An important set of parameters in my model concerns the elasticities of substitution across varieties of nontradable goods, between tradable and nontradable goods, and across countries.[11] The elasticities of substitution between home- and foreign-produced tradable goods and across foreign countries are assumed to be 2 (Obstfeld and Rogoff, 2005, 2007). The elasticity of substitution between tradable and nontradable goods is set at 0.6 based on the existing literature (Mendoza, 1995; Lane and Milesi-Ferretti, 2004). The elasticity of substitution across varieties of nontradable goods, ε, is set to 11, implying a steady state mark-up of 1.1 (Clarida, Galí, and Gertler, 1999, 2002).

For my benchmark case, the Frisch elasticity ($1/\psi$) is assumed to be 2/3 (in other words, $\psi = 1.5$).[12] For the monetary policy parameters, I follow Clarida, Galí, and Gertler (1998) and choose $\rho = 0.75$ and $\phi_\pi = 1.5$. I set the values of the AR (1) coefficients at 0.9 for productivity shocks to both the tradable and nontradable goods sectors, consistent with the literature (e.g., Aguiar and Gopinath, 2007). It is reasonable to assume that the volatility of productivity shocks in emerging market economies is higher than in advanced countries (García-Cicco, Pancrazi, and Uribe, 2010), so I set the standard deviation of the tradable sector productivity shock at $\sigma_a^H = 0.02$ and the standard deviation of the nontradable productivity shock at $\sigma_a^N = 0.015$. I borrow the parameter values of the persistence and stan-

[11] Obstfeld and Rogoff (2005) include a detailed discussion regarding parameter selection in such models and review relevant empirical studies.

[12] Estimates of this parameter range from 0.25 to 1. Given the gap between macro- and micro-level estimates of labor supply elasticity and the informal nature of labor markets in developing countries, I set the baseline labor supply elasticity to be slightly higher than the common value used for developed countries.

dard deviation of the foreign interest rate shock from Devereux, Lane, and Xu (2006), and choose $\rho_r = 0.46$ and the standard deviation parameter $\sigma_r = 0.012$. For terms-of-trade shocks, I follow Mendoza (1995) and choose $\rho_s = 0.47$ and $\sigma_s = 0.047$.

3.4 Baseline Results

I now present the main results of the model and evaluate the temporary consumption effects and welfare effects, both at the aggregate level and across types of households, of adopting various monetary policy rules. The baseline policy rule for the central bank is inflation targeting.[13] Two alternative policy rules are also considered: a fixed nominal exchange rate and nominal exchange rate smoothing, the latter of which is akin to the "leaning against the wind" approach ostensibly adopted by many emerging market central banks.

3.4.1 Temporary consumption effects

To understand the dynamics of key variables in the model, I begin by analyzing their responses to a positive productivity shock in the home economy's tradable sector, which characterizes a period of high tradable-sector growth. This shock

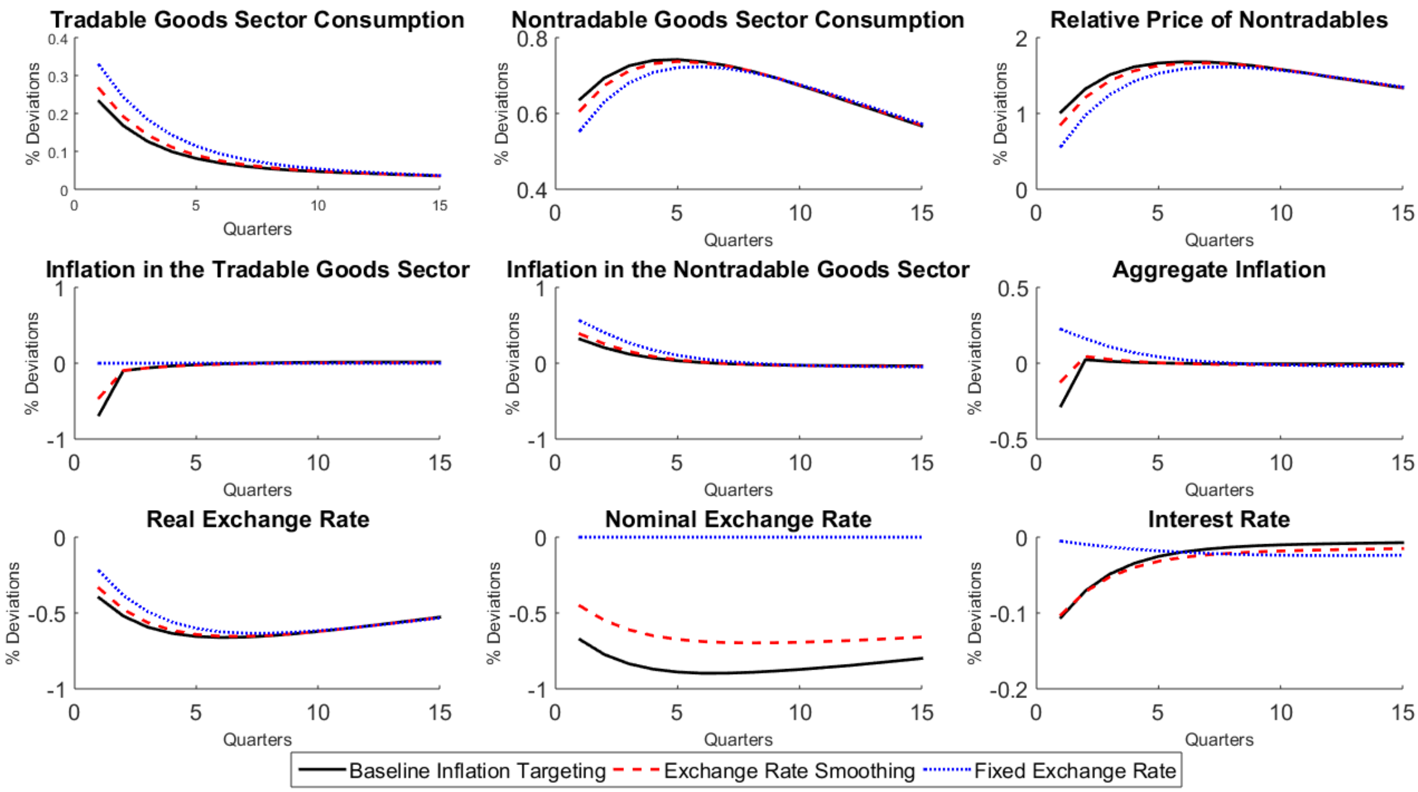
[13] The version of inflation targeting that I consider is in effect "strict" headline inflation targeting as it does not include other variables such as the output gap or wage inflation in the central bank's policy rule. I consider flexible inflation targeting later in this chapter.

is to be interpreted as a country-specific productivity shock that is transitory but persistent and, in most models (including this one) induces a real exchange rate appreciation. Given the lack of a well-defined welfare criterion when I focus on just the temporary effect, my approach is to evaluate the effects of various policy rules on the consumption patterns of the two types of households in response to the productivity shock.

Figure 3.2 shows the impulse responses for key variables under various monetary policy rules. A positive productivity shock of course improves aggregate consumption, so the distributional consequences are of greater interest. Household consumption in the traded goods sector is higher when the central bank temporarily reduces exchange rate appreciation relative to the case in which the central bank adopts inflation targeting. By contrast, household consumption in the nontradable sector is better under inflation targeting compared with any degree of exchange rate management. These distributional effects are monotonic in the weight ascribed to the nominal exchange rate in the central bank's policy rule, with the effects being largest in the case of a fixed exchange rate. As expected, the real exchange rate eventually adjusts through higher inflation and there is no difference in the long-run path of the real exchange rate independent of the policy rule.

Why do households in the tradable sector do better under a policy rule that involves nominal exchange management rather than inflation targeting? These households do not enjoy the benefits of higher productivity in the tradable sector

Figure 3.2: Impulse Responses to a Positive Productivity Shock in the Tradable Goods Sector



Notes: This figure shows the responses of several variables to a one standard deviation productivity shock to the home economy's tradable goods sector. Three monetary policy rules are considered. The black solid lines are impulse responses under an inflation-targeting rule, the dashed red lines represent impulse responses under an exchange rate smoothing rule, and the dotted blue lines show impulse responses under a fixed exchange rate regime. The responses are all expressed as percentage deviations from the steady-state values of the corresponding variables. A decline in the exchange rate (both nominal and real) indicates appreciation.

as much as households in the nontradable sector because the shock leads to a sharp increase in the relative price of nontradable goods. A temporary increase in the productivity of tradable goods production drives up the relative price of nontradable goods through two channels: an increase in the price of nontradable goods and a decrease in the price of tradable goods. Since the price of tradable goods is determined in international markets and priced in the foreign currency, the nominal exchange rate directly pins down its price in domestic currency.

When the monetary policy rule involves inflation targeting, the home currency appreciates following the positive productivity shock, leading to a drop in the price of tradable goods. As a result, the relative price of nontradable goods tends to rise even more. By contrast, if the central bank offsets or dampens nominal exchange rate appreciation, tradable goods prices do not adjust as much and the burden of the relative price adjustment falls to the nontradable sector. Price stickiness in that sector implies that the increase in nontradable goods prices is more gradual, so the relative price of nontradable goods adjusts more slowly. Thus, households in the tradable sector enjoy a relatively more favorable relative price and achieve higher consumption levels temporarily, compared with the scenario of an inflation-targeting central bank. In fact, the more the central bank manages the nominal exchange rate, the smoother the relative price and the higher the consumption gain of households in the tradable sector relative to the inflation-targeting case.[14]

[14]Since the tradable sector has flexible prices, employment and wage responses in that sector are similar across policy rules when the sector experiences a productivity shock.

This process, despite its similarity to the traditional Balassa-Samuelson effect, differs in the underlying mechanism. In the Balassa-Samuelson framework, higher productivity growth in the tradable sector pushes up wages in that sector and, to equalize wages across sectors, the relative price of nontradable goods must rise. In my model, a temporary increase in productivity in the tradable sector drives up the relative price of nontradable goods not through wage equalization, since labor is assumed to be immobile, but through household demand for tradable and nontradable goods.

3.4.2 Welfare effects

Next, I turn to an evaluation of the welfare effects of various policy rules using the welfare criterion defined in Section 3.3.6. Table 3.2 shows the implications under various policy rules for both temporary consumption effects and welfare effects. While targeting the nominal exchange rate provides temporary benefits to households working in the tradable sector relative to those working in the nontradable sector, the welfare effects are, surprisingly, reversed. Under the welfare criterion, households working in the tradable sector do worse under either of the policies that involve exchange rate management. By contrast, households working in the nontradable sector do marginally better under the welfare criterion when the central bank does not follow inflation targeting. More interestingly, aggregate household welfare in the economy is also slightly lower when the central bank manages the nominal exchange rate. These results all run in the same direction and are

Table 3.2: Temporary Consumption Effects and Welfare Effects under Nominal Exchange Rate Management

Scenario	*T Households*		*NT Households*		*Aggregate*	
	Temp.	*Welfare*	*Temp.*	*Welfare*	*Temp.*	*Welfare*
Exchange Rate Smoothing	0.11%	-0.03%	-0.07%	0.01%	0.04%	-0.01%
Fixed Exchange Rate	0.39%	-0.12%	-0.24%	0.05%	0.14%	-0.06%

Notes: This table shows the temporary consumption gains (or losses) and welfare gains from two policy rules–exchange rate smoothing and a fixed exchange rate–relative to an inflation targeting rule. The numbers are expressed in percentage points of cumulative consumption gains/losses over the short run (16 quarters) or percentage points of permanent consumption gains/losses relative to the baseline policy rule under the welfare criterion. "T households" refers to households working in the tradable goods sector; "NT households" refers to households working in the nontradable goods sector.

stronger when the central bank's policy rule involves a fixed exchange rate rather than exchange rate smoothing.

A key point to keep in mind is that the temporary effects on consumption are based on a scenario in which there is a transitory positive shock to productivity in the traded goods sector, namely during periods of booming exports. So my statements about temporary consumption effects are conditional on that specific shock. When conducting welfare evaluations, I of course need to consider random productivity shocks, both positive and negative. In this case, a monetary policy rule that attempts to stabilize the nominal exchange rate magnifies the volatility of household consumption in the tradable sector but reduces consumption volatility for households in the nontradable sector. Since welfare levels in my model depend crucially on the volatility of consumption, households working in the tradable sector paradoxically attain a lower level of welfare if monetary policy deviates from inflation targeting.

In short, a policy of stabilizing the exchange rate to temporarily benefit households in the traded goods sector can generate unfavorable welfare consequences for those very households and for the economy as a whole.

3.4.3 Sensitivity analysis

As noted earlier, it is difficult to pin down the values of certain parameters in my model due to the dearth of relevant empirical evidence for emerging market economies. I now report sensitivity tests to evaluate the impact of a few key parameters on both temporary consumption effects and welfare effects. This exercise also provides further insights into the mechanisms underlying my key results.

The distributional effects are most significant when the elasticity of substitution between tradable and nontradable goods is smaller, the share of tradable sector output is not large, and the Frisch elasticity of labor supply is high. My key conclusions concerning the distributional consequences of alternative monetary policy rules are preserved across a broad range of values for these key parameters.

Table 3.3: Sensitivity of Results to Key Parameters

Value	*Scenario*	*T Households*		*NT Households*		*Aggregate*	
		Temp.	*Welfare*	*Temp.*	*Welfare*	*Temp.*	*Welfare*
A. Elasticity of Substitution between Tradable and Nontradable Goods (baseline: ξ = 0.6)							
0.5	Exchange Rate Smoothing	0.20%	-0.06%	-0.21%	0.05%	0.03%	-0.02%
	Fixed Exchange Rate	0.73%	-0.32%	-0.77%	0.24%	0.13%	-0.09%
0.6	Exchange Rate Smoothing	0.11%	-0.03%	-0.07%	0.01%	0.04%	-0.01%
	Fixed Exchange Rate	0.39%	-0.12%	-0.24%	0.05%	0.14%	-0.06%
0.7	Exchange Rate Smoothing	0.08%	-0.01%	-0.02%	0.00%	0.04%	-0.01%
	Fixed Exchange Rate	0.26%	-0.06%	-0.05%	0.00%	0.13%	-0.04%
B. Relative Size of Tradable Goods Sector (baseline: b = 0.6)							
0.5	Exchange Rate Smoothing	0.16%	-0.03%	-0.05%	0.00%	0.06%	-0.02%
	Fixed Exchange Rate	0.60%	-0.18%	-0.18%	0.02%	0.21%	- 0.10%
0.6	Exchange Rate Smoothing	0.11%	-0.03%	-0.07%	0.01%	0.04%	-0.01%
	Fixed Exchange Rate	0.39%	-0.12%	-0.24%	0.05%	0.14%	-0.06%
0.7	Exchange Rate Smoothing	0.07%	-0.02%	-0.08%	0.02%	0.03%	0.00%
	Fixed Exchange Rate	0.23%	-0.08%	-0.26%	0.07%	0.08%	-0.02%
C. Frisch Elasticity of Labor Supply (baseline: ψ = 1.5)							
1.0	Exchange Rate Smoothing	0.15%	-0.03%	-0.10%	0.02%	0.05%	-0.01%
	Fixed Exchange Rate	0.54%	-0.16%	-0.36%	0.08%	0.18%	-0.06%
1.5	Exchange Rate Smoothing	0.11%	-0.03%	-0.07%	0.01%	0.04%	-0.01%
	Fixed Exchange Rate	0.39%	-0.12%	-0.24%	0.05%	0.14%	-0.06%
2.0	Exchange Rate Smoothing	0.09%	-0.02%	-0.05%	0.01%	0.03%	-0.01%
	Fixed Exchange Rate	0.31%	-0.11%	-0.18%	0.04%	0.11%	-0.05%

Elasticity of substitution between tradable and nontradable goods

The elasticity of substitution between tradable and nontradable goods (ξ) determines how responsive the relative price of nontradable goods is to productivity shocks in the tradable sector. When the elasticity of substitution is low, a temporary increase (decrease) in the supply of tradable goods when that sector experiences a positive productivity shock is likely to drive up (down) the relative price of nontradable goods to a greater extent. As a result, the distributional effects of monetary policy are also likely to be larger.

As shown in Table 3.3 (Panel A), the sizes of both temporary consumption effects and welfare effects of nominal exchange rate management depend on this elasticity of substitution. When the elasticity is lower, the temporary consumption gains of households working in the tradable sector and temporary consumption losses of households working in the nontradable sectors both increase. Similarly, the absolute values of welfare effects are also larger when the elasticity is lower. The temporary aggregate consumption effects do not change much with variations in this parameter, but the negative welfare effects of exchange rate management tend to increase as this elasticity decreases.

Share of tradable goods sector output

The share of tradable goods sector output (b) affects the relative share of tradable goods in the final consumption bundle and, consequently, influences relative price fluctuations. As shown in Table 3.3 (Panel B), both the temporary consumption gains and the welfare losses from the central bank's exchange rate management are smaller (in absolute terms) for households working in the tradable sector when the share of tradable sector output is higher. This is because, as the tradable sector accounts for a larger share, the home economy converges to a flexible price economy in which monetary policy does not have real effects. By contrast, as the relative size of the tradable sector decreases, the temporary consumption gains and welfare losses for households working in this sector both increase. Aggregate temporary consumption gains and welfare losses behave similarly.

When the relative size of the tradable sector increases, aggregate inflation is more sensitive to exchange rate policy because tradable goods prices are determined by the nominal exchange rate. This increases the impact of nominal exchange rate management on households working in the nontradable sector. The model confirms this intuition as the temporary consumption losses and welfare gains of households working in the nontradable sector increase when b is larger.

Frisch elasticity of labor supply

The Frisch elasticity of labor supply is the elasticity of labor supply conditional on a fixed level of consumption. In the model, it is given by the inverse of the parameter ψ. In Table 3.3 (Panel C), I compare the temporary consumption effects and welfare levels under various values of ψ. The results are intuitive. The sizes of the temporary consumption effects and welfare effects are larger when the Frisch elasticity of labor supply is higher (corresponding to a smaller ψ). The underlying reason for this result is that, when the Frisch elasticity of labor supply is higher, the household labor supply is more responsive to changes in real wages. When the central bank manages the nominal exchange rate, the real wage for households working in the tradable sector is higher for a given positive productivity shock, so the gain in consumption increases as the labor supply response increases. For the same reason, the temporary consumption loss for households working in the nontradable sector is higher.

3.5 Extensions

In this section, I discuss extensions of the model that enable me to study a broader range of policy questions. First, targeting the real exchange rate leads to temporary consumption effects and welfare effects that are almost identical to the effects of targeting the nominal exchange rate. Second, I find that the distributional effects of nominal exchange rate management are larger when the economy is subject to controls on cross-border capital flows. I also find that a fixed exchange rate delivers worse outcomes relative to inflation targeting even in terms of temporary consumption effects–for households in both the traded goods sector and the aggregate economy–when the economy faces positive shocks to productivity in the nontradable sector or to foreign interest rates. It is important to emphasize here that I cannot compare consumption and welfare gains or losses across distinct versions of the basic model since they have different steady states. My comparisons are about the effects of monetary policy rules *conditional* on a particular model setting.

3.5.1 Real exchange rate management

Calvo, Reinhart, and Vegh (1995) document that emerging market central banks often try to target the real exchange rate, even though such targeting is effective only temporarily and could even generate aggregate instability (Uribe, 2003). Nevertheless, in the short run, real exchange rate changes do tend to be closely correlated with nominal exchange rate changes (see, e.g., Burstein and Gopinath, 2014). To evaluate the implications of real exchange rate targeting, I modify the baseline interest rate rule in equation (3.12) to include the change in the real exchange rate rather than in the nominal exchange rate:

$$log\left(\frac{R_t}{\overline{R}}\right) = \rho \ log\left(\frac{R_{t-1}}{\overline{R}}\right) + (1-\rho)\left[\phi_\pi log\left(\frac{\pi_t}{\overline{\pi}}\right) + \phi_e log\left(\frac{q_t^e}{q_{t-1}^e}\right)\right] \tag{3.15}$$

where q_t^e is the real exchange rate.

In Table 3.4 (Panel A), I compare the temporary consumption effects and welfare effects of targeting the nominal and real exchange rates, with inflation targeting serving as the benchmark rule. There is little difference between the two exchange rate targets. In the short run, prices are sticky, so the two exchange rates are correlated and the corresponding interest rate rules suggest similar policy rates. In technical terms, because $log(q^e_t/q^e_{t-1}) = log(e_t/e_{t-1}) - \pi_t$, the only difference between targeting real and targeting nominal exchange rates is the implied response to inflation. In the long run, prices become flexible, so there is no difference in welfare outcomes between the two targeting rules.

3.5.2 Capital controls

Emerging market economies often supplement monetary policy with capital controls to reduce capital flow and currency volatility, and also to make it easier to manage the exchange rate. These controls can take the form of bureaucratic restrictions on international capital flows (Chang, Liu, and Spiegel, 2015), a tax on international financial transactions (Jeanne and Korinek, 2010; Gabaix and Maggiori, 2015), or simply a wedge in the uncovered interest parity equation (Farhi and Werning, 2014).

I introduce capital controls in a manner similar to Chang, Liu, and Spiegel (2015) by setting the parameter ψ_B, which represents the one-period portfolio holdings cost for foreign bond holdings, at 1 for the case with capital controls. This is a plausible value for this parameter based on the estimates of García-Cicco, Pancrazi, and Uribe (2010). Under the capital controls scenario, households working in the tradable goods sector face higher costs when smoothing consumption intertemporally using foreign bonds. This renders the relative price between trad-

Table 3.4: Temporary Consumption Effects and Welfare Effects under Alternative Policy Experiments

Scenario	*T Households*		*NT Households*		*Aggregate*	
	Temp.	*Welfare*	*Temp.*	*Welfare*	*Temp.*	*Welfare*
A. Real Exchange Rate Management						
Nominal Exchange Rate	0.11%	-0.03%	-0.07%	0.01%	0.04%	-0.01%
Real Exchange Rate	0.10%	-0.03%	-0.07%	0.01%	0.04%	-0.01%
B. Capital Controls						
Exchange Rate Smoothing	0.19%	-0.09%	-0.08%	0.04%	0.09%	-0.04%
Fixed Exchange Rate	0.97%	-0.55%	-0.38%	0.22%	0.43%	-0.24%
C. Fiscal Policy						
Tax on Nontradable Goods	0.36%	0.00%	-0.59%	0.00%	-0.03%	0.00%
Subsidy on Nontradable Goods	-0.37%	0.00%	0.60%	0.00%	0.02%	0.00%
D. Flexible Inflation Targeting						
Exchange Rate Smoothing	0.25%	-0.01%	-0.16%	0.01%	0.09%	0.00%
Fixed Exchange Rate	0.78%	-0.16%	-0.48%	0.06%	0.28%	-0.07%

Notes: This table shows the temporary consumption gains (or losses) and welfare gains from alternative policy rules relative to an inflation targeting rule under alternative policy experiments. Panel A compares the effects of nominal and real exchange rate targeting relative to pure inflation targeting. For the results shown in Panel B, capital controls are imposed regardless of the policy regime. As shown in Panel C, the monetary policy rule is inflation targeting in the baseline and alternative scenarios. The latter two scenarios involve a 3 percent tax or subsidy, respectively, on nontradable goods. As shown in Panel D, the baseline (inflation targeting) and exchange rate smoothing rules include an output gap term. The numbers are expressed in percent of cumulative consumption gains/losses over the short run (16 quarters) or percentage points of permanent consumption gains/losses relative to the baseline policy rule under the welfare criterion.

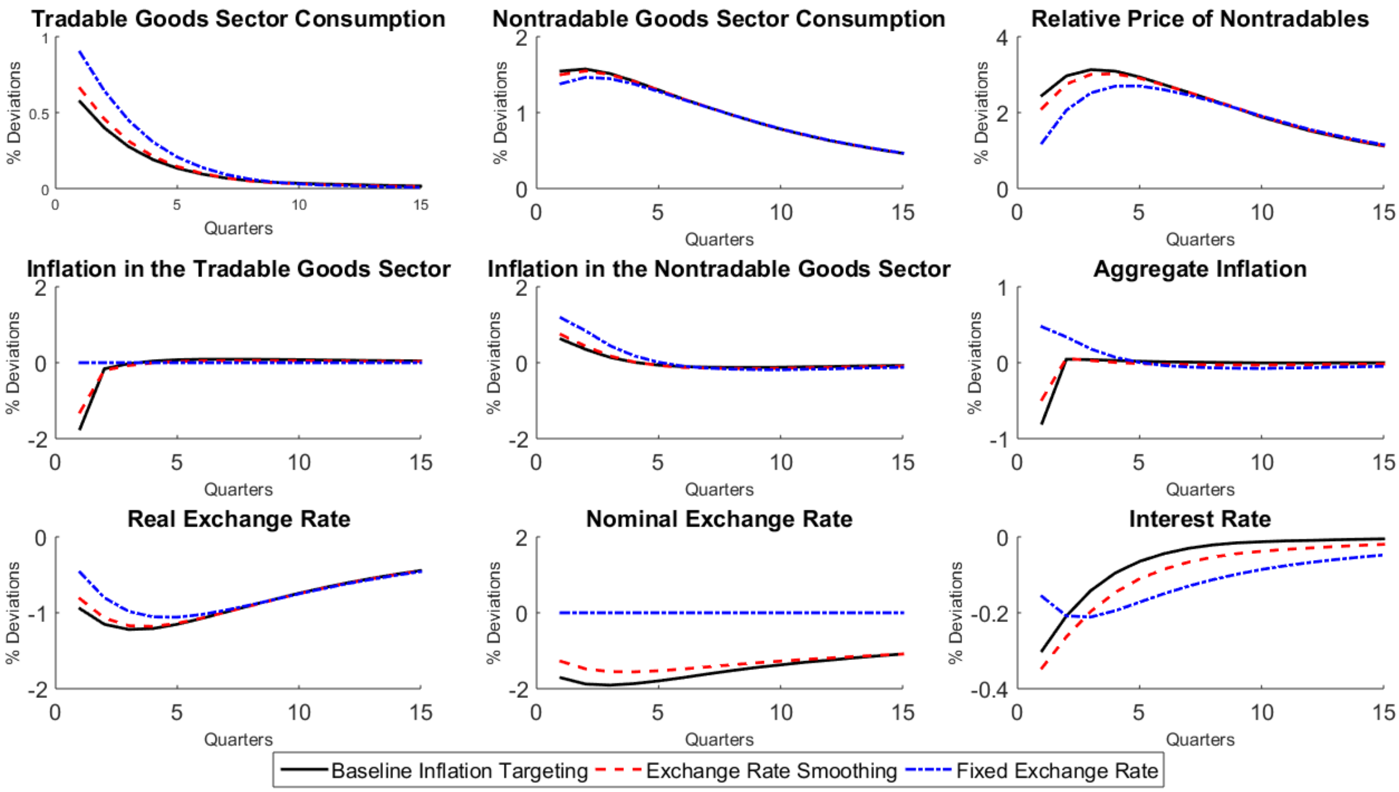
able and nontradable goods more responsive to productivity shocks as well as alternative monetary policy rules.[15]

Figure 3.3 shows that household consumption levels are more responsive to productivity shocks than in the baseline model. Moreover, monetary policy has larger distributional effects compared with the baseline model. When faced with capital controls, households working in the tradable goods sector spend more of their income when a positive productivity shock hits their sector, resulting in an even larger increase in the relative prices of nontradable goods. Managing the nominal exchange rate has larger distributional effects in the short run, following the same mechanism discussed in the baseline model but with larger magnitudes. Thus, in an environment with capital controls, emerging market central banks are more likely to use exchange rate management if they are subject to political pressures from households in the tradable goods sector, as the effects of such policies are greater relative to inflation targeting.

Table 3.4 (Panel B) shows the temporary consumption effects and welfare effects of alternative monetary policy rules in an economy with capital controls. Relative to the baseline model with unrestricted capital flows (Table 3.2), the distributional effects are stronger under capital controls. Notably, not only are these effects stronger for both types of households, the aggregate effects are also larger. In other words, while policymakers have a stronger incentive to use monetary

[15] Jeanne and Korinek (2010) and Jeanne (2012) show that capital controls can be used to affect the real exchange rate in a model that has tradable and nontradable goods, although their models are entirely real–there is no money or monetary policy.

Figure 3.3: Impulse Responses to a Positive Productivity Shock in the Tradable Goods Sector (with Capital Controls)



Notes: This figure shows the responses of several variables to a one-standard-deviation productivity shock to the home economy's tradable goods sector. Capital controls are imposed regardless of the policy regime. Three monetary policy rules are considered. The solid black lines are impulse responses under an inflation targeting rule, the dashed red lines represent impulse responses under an exchange rate smoothing rule, and the dotted blue lines show impulse responses under a fixed exchange rate regime. The responses are all expressed as percentage deviations from the steady-state values of the corresponding variables. A decline in the exchange rate (both nominal and real) indicates appreciation.

policy to achieve temporary distributional objectives, this comes at a higher cost in terms of aggregate welfare.

3.5.3 Fiscal policy

As discussed in the baseline model, developing countries' central banks can use monetary policy to achieve certain distributional consequences. By targeting the nominal exchange rate, the central bank can smooth the adjustment of the relative price of nontradable goods and temporarily increase the consumption of households working in the tradable goods sector. However, monetary or exchange rate policies are not necessarily the right tools with which to address domestic or external shocks in an open economy setting.

Instead, fiscal policy is often the more efficient and direct policy instrument for redistribution across households.[16] The tax and transfer system in emerging market countries is typically not sophisticated enough to allow for state-contingent direct transfers that can help complete financial markets and achieve perfect risk-sharing. Nevertheless, there are simple fiscal tools that are feasible to implement and could attain some of these benefits. In particular, I study the impact of a

[16]Farhi, Gopinath, and Itskhoki (2014) show that a small set of conventional fiscal instruments can robustly replicate the real allocations attained under a nominal exchange rate devaluation in a dynamic New Keynesian open economy environment. However, theirs is a one-sector model without financial frictions or heterogeneous households. Schmitt-Grohé and Uribe (2011) show that, in a model with downward wage rigidity and an inelastic labor supply, a payroll tax subsidy can replicate the effects of a nominal devaluation. Correia, Nicolini, and Teles (2008) and Correia et al. (2013) show that fiscal instruments can replicate the effects of optimal monetary policy. This section of my chapter is related to these papers, but none of them addresses distributional issues.

proportional tax and subsidy on nontradable goods and compare their temporary consumption effects and welfare effects with the effects of nominal exchange rate targeting. My interest here is in analyzing how fiscal and monetary policies interact in a small open economy setting with financial frictions in determining distributional effects of various shocks. This allows me to make a normative statement about whether fiscal policy would be a more effective tool than monetary policy even if the government's focus is on achieving specific distributional objectives.

To be more specific, I consider alternative fiscal policy regimes with varying tax rates on nontradable goods: the baseline case with no taxes; a case with a 3 percent tax on nontradable goods, with the proceeds of the tax distributed in a lump sum fashion across all households in the economy; and a case with a 3 percent subsidy on nontradable goods, with the subsidy financed through a lump sum tax on all households. The tax/subsidy is set as a wedge between labor wages and goods prices. Furthermore, to facilitate comparison between policy regimes, there is a direct transfer between households to keep their respective steady-state consumption levels unchanged from the baseline case. Thus, the shift in relative prices is the main channel through which fiscal policy has temporary consumption effects. Regardless of the fiscal policy setting, the monetary policy rule is pure inflation targeting.

The results are summarized in Table 3.4 (Panel C). A tax on nontradable goods has distributional effects that are similar to nominal exchange rate targeting. The imposition of taxes on nontradable goods implies that households working in the tradable goods sector will be better off after a positive productivity shock to that sector, due to the relative price effect. By contrast, households working in the nontradable goods sector exhibit lower temporary consumption under this regime. The results are reversed but symmetric when there is a subsidy on nontradable goods. While the temporary consumption effects are similar to a policy of targeting the nominal exchange rate, the welfare effects differ. In fact, fiscal policy is close to welfare neutral, at both the household and aggregate levels, because the constant sales tax (or subsidy) on nontradable goods does not affect intertemporal household choices.

The implication is that fiscal policy can in principle be more effective than exchange rate policy for attaining distributional objectives. While previous authors have made the point that fiscal policy can be more effective than exchange rate policy (or can serve as a substitute when there are constraints on exchange rate management) in an open economy setting, my contribution here is to show that this is true even when the objectives are related to distributional rather than aggregate consequences.

3.5.4 Flexible inflation targeting

In practice, emerging market central banks set interest rates to manage not just inflation and the exchange rate but also the output gap (the deviation of output from its steady state or trend level). In a specific setting that incorporates local currency pricing, Engel (2011) finds that the optimal instrument rule involves responding only to the deviation of inflation from its target level even if the central bank cares about inflation, output, and exchange rate misalignment. Nevertheless, it is relevant in a more general setting to consider flexible inflation targeting as the baseline for assessing the distributional effects of nominal exchange rate management. This is consistent with the basic formulation of the Taylor (1993) rule for monetary policy.

To this end, I modify the interest rate rule in equation (3.12) to include a positive weight on the output gap. This yields the following operational rule for monetary policy:

$$log\left(\frac{R_t}{\overline{R}}\right) = \rho\ log\left(\frac{R_{t-1}}{\overline{R}}\right) + (1-\rho)\left[\phi_\pi log\left(\frac{\pi_t}{\overline{\pi}}\right) + \phi_y log\left(\frac{Y_t}{\overline{Y}}\right) + \phi_e log\left(\frac{e_t}{e_{t-1}}\right)\right] \tag{3.16}$$

where ϕ_y is the output gap response coefficient, Y_t represents output in period t, and $\overline{Y}$ denotes steady-state output. Since a period in my model is equal to one quarter, I set ϕ_y to 0.125 as the baseline value. As discussed in Galí (2015) and Smets and Wouters (2007), this matches the annualized coefficient value proposed in Taylor (1993).

I summarize the results obtained using this more general formulation of monetary policy rules in Table 3.4 (Panel D). The baseline is flexible inflation targeting and the output gap term also enters the exchange rate smoothing rule but does not appear in the fixed exchange rate rule. The temporary distributional effects of exchange rate targeting rules relative to the baseline are larger when the central bank responds to the output gap. This is because a positive productivity shock now leads to a positive output gap, which drives up the interest rate and, consequently, the nominal exchange rate as well. Hence, exchange rate management now involves large temporary consumption gains for households in the tradable goods sector relative to the baseline rule. Households in the nontradable goods sector, by contrast, do significantly worse in terms of temporary consumption relative to the baseline rule because the adjustment of relative prices between tradable and nontradable goods is less favorable to them.

As expected, the welfare effects are similar to the baseline experiments with strict inflation targeting, with the welfare of households in the tradable goods sector and aggregate welfare both lower when the central bank incorporates the exchange rate in its operational rule. The welfare effects again mostly reflect the consumption volatility channel as nominal rigidities play no role in the long run.

3.5.5 Alternative shocks

When the central bank uses monetary policy to achieve certain distributional objectives, it commits to a particular policy rule. However, this may have unexpected consequences when the economy is hit by shocks other than the productivity shocks to the tradable goods sector that I have emphasized up to this point. I now examine the temporary consumption effects and welfare effects of nominal exchange rate management when the economy faces three other types of shocks.[17] The results discussed below are summarized in Table 3.5.

Productivity shocks in the nontradable goods sector

I first consider a scenario in which the economy faces productivity shocks only in the nontradable goods sector (see the first two rows of Table 3.5). In this case, relative to inflation targeting, nominal exchange rate management has adverse consequences for households in the tradable goods sector in terms of both temporary consumption and welfare. A positive productivity shock in the nontradable goods sector drives down the relative price of nontradable goods, leading to higher household consumption in the tradable goods sector. Following the same mechanism as in the baseline model, nominal exchange rate management slows the adjustment in the relative price compared with a policy of inflation targeting, thus hurting households working in the tradable goods sector and benefiting those working in the nontradable goods sector. Under a fixed exchange rate, households in the traded goods sector face a consumption loss of 0.34 percent (over 16 quarters) relative to pure inflation targeting; under the welfare criterion, their welfare loss amounts to 0.16 percent of lifetime consumption.

[17] In this section, I study the temporary consumption effects and welfare effects separately when the economy faces only one specific type of shocks at a time. This decomposition of the effects of distinct types of shocks is valid given the theoretical result reported in Schmitt-Grohé and Uribe (2004).

Table 3.5: Temporary Consumption Effects and Welfare Effects under Alternative Shocks

Scenario	*T Households*		*NT Households*		*Aggregate*	
	Temp.	*Welfare*	*Temp.*	*Welfare*	*Temp.*	*Welfare*
A. Productivity Shocks in the Nontradable Goods Sector						
Nominal Exchange Rate	-0.10%	-0.04%	0.07%	0.02%	-0.04%	-0.02%
Real Exchange Rate	-0.34%	-0.16%	0.22%	0.06%	-0.12%	-0.07%
B. Terms of Trade Shocks						
Exchange Rate Smoothing	0.01%	0.01%	-0.01%	-0.01%	0.00%	0.00%
Fixed Exchange Rate	0.11%	0.02%	-0.07%	-0.01%	0.04%	0.01%
C. Foreign Interest Rate Shocks						
Exchange Rate Smoothing	-0.01%	-0.01%	0.00%	0.00%	0.00%	0.00%
Fixed Exchange Rate	-0.46%	-0.09%	0.27%	0.04%	-0.06%	-0.04%

Notes: This table compares the temporary consumption gains (or losses) and welfare gains from two policy rules—exchange rate smoothing and a fixed exchange rate—relative to an inflation targeting rule when the home economy faces distinct types of shocks. The numbers are expressed in percentage points of cumulative consumption gains/losses over the short run (16 quarters) or percentage points of permanent consumption gains/losses relative to the baseline policy rule under the welfare criterion. "T households" refers to households working in the tradable goods sector; "NT households" refers to households working in the nontradable goods sector.

Terms-of-trade shocks

Terms-of-trade fluctuations are important in driving fluctuations in emerging market economies (see, e.g., Mendoza, 1995). As seen in the second panel of Table

3.5 (third and fourth rows), I examine the distributional effects of monetary policy when the home economy faces terms-of-trade shocks. A higher terms of trade value implies higher prices for home-produced tradable goods in the foreign currency. Hence, targeting the nominal exchange rate implies higher relative prices of tradable goods than is the case with inflation targeting. This temporarily benefits households working in the tradable goods sector. However, the welfare consequences of the particular choice of policy rule are minimal when the economy is exposed to these shocks because import and export prices are perfectly flexible.

Foreign interest rate shocks

Emerging market economies are exposed to foreign interest rate shocks that have significant effects on their business cycles and exchange rate fluctuations.[18] When considering such shocks, I find that a fixed exchange rate benefits households working in the nontradable goods sector but hurts households working in the tradable goods sector in terms of both temporary consumption and welfare (see Table 3.5, last two rows).

A temporary increase in the foreign interest rate tends to cause the domestic currency to depreciate and drive up the demand for home-produced tradable goods. In this case, stabilizing the nominal exchange rate implies a higher domestic interest rate and encourages households to save more. Households working

[18]For some early work see, for example, Neumeyer and Perri (2005) and Aguiar and Gopinath (2006).

in the nontradable goods sector are better off in terms of temporary consumption compared with the outcome under an inflation targeting regime because of a smaller increase in the relative price of tradable goods. By contrast, households working in the tradable goods sector are not as well off. The welfare effects for both types of households have the same signs as temporary consumption effects (better for households in the nontradable goods sector, worse for those in the tradable goods sector) because targeting the nominal exchange rate leads to more volatile nominal interest rates. Since only households working in the tradable goods sector have access to financial markets, they are exposed to interest rate volatility, rendering their consumption more volatile.[19]

3.6 Concluding Remarks

In this chapter, I developed a two-sector, heterogeneous agent model with incomplete financial markets that allowed me to jointly examine the distributional effects as well as aggregate welfare implications of nominal exchange rate management. The features that I incorporated in the model–incomplete financial markets, sticky prices in the nontradable sector, and limited labor mobility across sectors–make it especially relevant for the analysis of monetary policy in emerging market economies.

[19]Some authors have argued that emerging market economies face highly persistent foreign interest rate shocks (see, e.g., García-Cicco, Pancrazi, and Uribe, 2010; Chang, Liu, and Spiegel, 2015). Allowing for more persistent foreign interest rate shocks magnifies the effects discussed in this sub-section.

My main result is that, relative to inflation targeting, exchange rate management has a positive but temporary effect on household consumption in the tradable sector when that sector faces productivity shocks. Indeed, political pressure from the tradable sector, in fear of a loss of external competitiveness due to exchange rate appreciation, is often a key reason that emerging market central banks try to manage the nominal exchange rate. However, I find that such a policy can actually reduce the welfare of households in the traded goods sector as it increases their consumption volatility. Moreover, such a policy can have negative aggregate consequences on consumption in periods of high tradable-sector growth.

This result becomes particularly relevant now as central banks in emerging market economies are busy defending their currencies. For many emerging market economies, exchange rate stability is a desirable policy objective because it helps maintain export competitiveness during booms, but central banks should also realize that sticking to this rule in downturns will hurt the tradable sector and reduce aggregate welfare. The distributional effects of nominal exchange rate management are not as simple as people typically think.

APPENDIX A

APPENDIX TO CHAPTER 1

A.1 The Competitive Equilibrium of the MS-DSGE Model

In this section, I present the derivation of the competitive equilibrium of the MS-DSGE model developed in Chapter 1.

A.1.1 Profit-maximization problem

Here, the profit-maximization problem is similar to that presented in Galí and Monacelli (2005). Firms maximize profits given in equation (1.12) and the optimality condition is given by:

$$\sum_{k=0}^{\infty} \theta^k E_t \left\{ Q_{t,t+k} Y_{t+k} \left(P^*_{H,t} - \frac{\varepsilon}{\varepsilon - 1} MC_{t+k} \right) \right\} \tag{A.1}$$

where MC is the nominal marginal cost. Following the traditional literature, I introduce an employment subsidy τ such that $1 - \tau = \frac{\varepsilon}{\varepsilon - 1}$ so the flexible price equilibrium is efficient and the goal of the monetary policy is to eliminate inefficiency due to nominal rigidities.

Then, I log-linearize the above first-order condition around its steady state:

$$p^*_{H,t} = p_{H,t-1} + \sum_{k=0}^{\infty}(\beta\theta)^k E_t\{\pi_{H,t+k}\} + (1-\beta\theta)^k E_t\{\widehat{mc}_{t+k}\} \tag{A.2}$$

Combining it with the price distribution, the inflation dynamics of home goods can be written as below:

$$\widehat{\pi}_{H,t} = \beta E_t\{\widehat{\pi}_{H,t-1}\} + \frac{(1-\theta)(1-\beta\theta)}{\theta}\widehat{mc}_t \tag{A.3}$$

Lastly, the deviation of real marginal cost denoted by home goods can be written as below:

$$\begin{aligned} \widehat{mc}_t &= \sigma\widehat{c}_t + \phi\widehat{n}_t + \tfrac{1-a}{a}\widehat{q}_t - \widehat{a}_t \\ &= \sigma\widehat{c}_t + \phi\widehat{y}_t + \tfrac{1-a}{a}\widehat{q}_t - (1+\phi)\widehat{a}_t \end{aligned} \tag{A.4}$$

where $\widehat{q}_t$ is the percentage deviation of the real exchange rate from its steady state.

To sump up, the aggregate supply function can be written as:

$$\widehat{\pi}_{H,t} = \beta E_t\{\widehat{\pi}_{H,t-1}\} + \frac{(1-\theta)(1-\beta\theta)}{\theta}\left(\sigma\widehat{c}_t + \phi\widehat{y}_t + \frac{1-a}{a}\widehat{q}_t - (1+\phi)\widehat{a}_t\right) \tag{A.5}$$

A.1.2 Demand for home goods

Demand for home goods is the sum of domestic demand and foreign demand. By the market clearing condition, total demand is equal to total supply. Domestic demand for home goods is $a\left(\frac{P_{H,t}}{P_t}\right)^{-\eta} C_t$ from the household optimization problem. Aggregate foreign demand C_t^* is normalized such that its steady-state value is equal to the steady-state level of domestic output. Assuming a similar preference structure, foreign demand for home goods is $(1-a)\left(\frac{P_{H,t}}{P_{F,t}}\right)^{-\eta} C_t^*$. Therefore, demand for home goods can be written as equation (1.14). Furthermore, the log-linearized relationship can be written as

$$\begin{aligned} \widehat{y_t} &= a[-\eta(-\tfrac{1-a}{a})\widehat{q_t} + \widehat{c_t}] + (1-a)[-\eta(-\tfrac{1}{a})\widehat{q_t} + \widehat{c_t^*}] \\ &= \tfrac{1-a^2}{a}\eta\widehat{q_t} + a\widehat{c_t} + (1-a)\widehat{c_t^*} \end{aligned} \tag{A.6}$$

A.1.3 The log-linearized system of equations

Competitive equilibrium can be characterized by a system of 11 equations and 11 variables, out of which 8 are endogenous and 3 are exogenous. Here I write out the complete log-linearized system of equations with variables $\{\widehat{c_t}, \widehat{\pi}_{H,t}, \widehat{q_t}, \widehat{\pi}_t, \widehat{y_t}, \widehat{b_t^*}, \widehat{\Delta e_t}, \widehat{a_t}, \widehat{i_t}, \widehat{i_t^*}, \widehat{c_t^*}\}$ as their percentage deviations from their steady state values.

The resource constraint of the small open economy:

$$\widehat{y_t} = \widehat{c_t} + \widehat{b_t^*} - \frac{1}{\beta}\widehat{b_t^*} \tag{A.7}$$

The log-linearized Euler equation from the domestic bond-holding decision:

$$\widehat{c}_t = E_t\widehat{c}_{t+1} - \frac{1}{\sigma}(\widehat{i}_t - E_t\widehat{\pi}_{t+1}) \tag{A.8}$$

The interest rate parity:

$$\widehat{i}_t - E_t\widehat{\pi}_{t+1} = \widehat{i}^*_t + E_t\widehat{q}_{t+1} - \widehat{q}_t - \psi_B\widehat{b}^*_t \tag{A.9}$$

The definition of inflation:

$$\widehat{\pi}_t = \widehat{\pi}_{H,t} + \frac{1-a}{a}(\widehat{q}_t - \widehat{q}_{t-1}) \tag{A.10}$$

The definition of the real exchange rate:

$$\widehat{q}_t - \widehat{q}_{t-1} = \widehat{\Delta e}_t - \widehat{\pi}_t \tag{A.11}$$

The interest rate rule:

$$\widehat{i}_t = \rho\widehat{i}_{t-1} + (1-\rho)(\phi_\pi\widehat{\pi}_t + \phi_e\widehat{\Delta e}_t) \tag{A.12}$$

The productivity process:

$$\widehat{a}_t = \rho_a\widehat{a}_{t-1} + \varepsilon^a_t \tag{A.13}$$

The foreign demand process:

$$\widehat{c}_t^* = \rho_c \widehat{c}_{t-1}^* + \varepsilon_t^c \tag{A.14}$$

The regime-switching foreign interest rate process:

$$\widehat{i}_t^* = \rho_r(s) \widehat{i}_{t-1}^* + \varepsilon_t^r(s) \tag{A.15}$$

Equations (A.5) - (A.15) constitute the competitive equilibrium of the MS-DSGE model and its solution can be found using the algorithm illustrated by Farmer, Waggoner, and Zha (2011).

A.2 Loss Function Derivation

I shall follow the notation in De Paoli (2009) for welfare function derivation. As mentioned above, the pure quadratic approximation is conducted by approximating both the welfare function and the relevant first-order conditions up to the second order so that I can cancel out all first-order terms.

To begin with, the second-order approximation of the welfare function is given below:

$$
\begin{aligned}
W_{t_0} &= U_c\bar{C}E_{t_0}\sum\beta^t\left[\hat{c}_t-\hat{y}_t+\tfrac{1-\sigma}{2}\hat{c}_t^2-\tfrac{\phi+1}{2}(\hat{y}_t-\hat{a}_t)^2\right]+t.i.p.+O(\|\xi\|^3) \\
&= U_c\bar{C}E_{t_0}\sum\beta^t\left[w_y'y_t-\tfrac{1}{2}y_t'W_yy_t-y_t'W_ee_t-\tfrac{1}{2}w_{\hat{\pi}}\hat{\pi}_t^2\right]
\end{aligned}
\tag{A.16}
$$

where

$$
w_{\hat{\pi}}=\frac{\varepsilon}{\kappa},\quad w_y'=[-1,1,0]
$$

$$
W_y'=\begin{bmatrix}1+\phi & 0 & 0 & 0\\ 0 & -(1-\sigma) & 0 & 0\\ 0 & 0 & 0 & 0\\ 0 & 0 & 0 & 0\end{bmatrix}, W_e'=\begin{bmatrix}-(1+\phi) & 0 & 0\\ 0 & 0 & 0\\ 0 & 0 & 0\\ 0 & 0 & 0\end{bmatrix}
$$

Then I need to approximate relevant first-order conditions up to the second order, including the real exchange rate definition, the intertemporal Euler equation, demand for home goods, and aggregate supply.

First, the vectors and matrices derived from the real exchange rate definition are:

$$
f'y=[0,0,-a,-(1-a)],\quad f_e'=[0,0,0]
$$

$$
F_y'=\begin{bmatrix}0 & 0 & 0 & 0\\ 0 & 0 & 0 & 0\\ 0 & 0 & -a(1-\eta) & 0\\ 0 & 0 & 0 & -(1-a)(1-eta)\end{bmatrix}, F_e'=0
$$

Second, the vectors and matrices derived from the intertemporal Euler equation are:

$$c'y = [0, (1-\beta)\sigma, 0, (\beta-1)], \quad c'_e = [0, -\beta, 0]$$

$$C'_y = \begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & (\beta-1)\sigma^2 & 0 & \sigma(1-\beta) \\ 0 & 0 & 0 & 0 \\ 0 & \sigma(1-\beta) & 0 & (\beta-1) \end{bmatrix}, C'_e = \begin{bmatrix} 0 & 0 & 0 \\ 0 & \sigma\beta & 0 \\ 0 & 0 & 0 \\ 0 & \beta & 0 \end{bmatrix}$$

Third, the vectors and matrices derived from demand for home goods are:

$$d'y = [-1, a, -\eta, (1-a)\eta], \quad d'_e = [0, 0, 1]$$

$$D'_y = \begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & a(1-a) & 0 & -\eta a(1-a) \\ 0 & 0 & 0 & 0 \\ 0 & -\eta a(1-a) & 0 & \eta^2 a(1-a) \end{bmatrix}, D'_e = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & -a(1-a) \\ 0 & 0 & 0 \\ 0 & 0 & \eta a(1-a) \end{bmatrix}$$

Finally, the vectors and matrices derived from aggregate supply are:

$$a'_y = [\phi, \sigma, -1, 0], \quad a'_\pi = (\phi + 1)\frac{\sigma}{\kappa}$$

$$A'_y = \begin{bmatrix} \phi(2+\phi) & \sigma & -1 & 0 \\ \sigma & -\sigma^2 & \sigma & 0 \\ -1 & \sigma & -1 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix}, A'_e = \begin{bmatrix} -\phi(1+\phi) & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix}$$

After substituting the linear terms in the welfare function, I have:

$$[a_y \, d_y \, f_y \, c_y]L_x = w_y \tag{A.17}$$

The loss function can then be written as:

$$L_{t_0} = U_c \bar{C} E_{t_0} \sum \beta^t \left[\frac{1}{2} y'_t L_y y_t + y'_t L_e e_t + \frac{1}{2} l_{\hat{\pi}} (\hat{\pi}_t^H)^2 \right] + t.i.p. + O(\|\xi\|^3) \tag{A.18}$$

where

$$L_y = W_y + L_x(1)A_y + L_x(2)D_y + L_x(3)F_y + L_x(4)C_y \tag{A.19}$$

$$L_e = W_e + L_x(1)A_e + L_x(2)D_e + L_x(4)C_e \tag{A.20}$$

$$l_{\hat{\pi}} = w_{\hat{\pi}} + L_x(1)a_{\hat{\pi}} \tag{A.21}$$

The loss function is then used to compare welfare outcomes under a range of policy rules.

APPENDIX B

APPENDIX TO CHAPTER 2

B.1 Comparison of Simulated and Empirical Moments of Inflation

I compare empirical moments of inflation rates with moments from simulations of my model to assess the relevance of the model to emerging market economies. While it is not My objective to attain a precise match between model-generated and empirical moments, the incomplete markets version of the model does better at matching the empirical moments of data for emerging market economies.

The top panel of Table B.1 reports the standard deviations of overall CPI inflation, food inflation, and nonfood inflation, as well as the standard deviations of their innovations. Food inflation tends to be more volatile than nonfood inflation and emerging markets have more volatile inflation rates in all categories relative to advanced economies. The next two panels report moments from simulations of the complete and incomplete markets versions of the model in the chapter. The volatility of CPI inflation and nonfood inflation from the incomplete markets version of the model are close to the data; food inflation is more volatile in the model than in the data. Headline inflation targeting leads to less volatile food inflation but slightly more volatile nonfood inflation.

Table B.1: Comparison of Simulated and Empirical Moments of Inflation

	CPI Inflation		*Food Inflation*		*Nonfood Inflation*	
	Standard Deviations	*SD of Innovation*	*Standard Deviations*	*SD of Innovation*	*Standard Deviations*	*SD of Innovation*
Empirical Data						
Emerging Markets	3.49	3.26	5.00	5.61	2.92	3.72
Advanced Economies	1.48	1.32	2.45	2.75	1.10	1.24
Volatility Ratio	2.36	2.47	2.04	2.04	2.65	3.00
Simulations (Headline)						
Incomplete Markets	3.20	5.25	7.99	13.24	2.37	2.77
Complete Markets	1.17	1.87	2.67	4.38	0.93	1.13
Volatility Ratio	2.74	2.81	2.99	3.02	2.55	2.45
Simulations (Core)						
Incomplete Markets	4.43	7.26	9.99	16.45	0.96	1.33
Complete Markets	1.51	2.38	3.08	5.01	0.69	0.84
Volatility Ratio	2.93	3.05	3.24	3.28	1.39	1.58

Notes: The data used in constructing this table are from Walsh (2011), and are based on monthly price indices from 1985 – 2008. The numbers reported are medians for 23 emerging markets and 26 advanced economies. Standard deviations are based on the month-to-month log changes in the price indices. The standard deviation of innovations indicates the volatility of changes in food and nonfood inflation. Model simulations are done for 10,000 periods and based on different assumptions about financial markets.

B.2 Extension: Common Productivity Shocks in Both Sectors

I recomputed the model with a productivity shock common to the food and the nonfood domestic goods sectors (and, as before, markup and terms of trade

Table B.2: Welfare Comparisons under Different Inflation Targets

Scenario	*Welfare Gain*		*Weights in the Optimal Price Index*		
	Headline	*Optimal*	*Food Prices*	*Sticky Prices*	*Import Prices*
Baseline	0.16%	0.20%	0.35	0.65	0.00
Persistent Shocks	0.03%	0.04%	0.70	0.02	0.28
Transitory Shocks	0.29%	0.50%	1.00	0.00	0.00

Notes: The optimal price index comprises food prices, sticky nonfood domestic goods prices, and import prices. Welfare gains under different parameter values are derived as permanent consumption gains relative to strict core inflation targeting.

shocks as well). This ought to preserve the welfare gains from targeting inflation in the headline CPI or the optimal price index as there are no longer any shocks specific to the rigid price sector. This is indeed what I find, confirming my main results. The results go through whether the common productivity shock is transitory (food sector shock) or more persistent (sticky price sector shock). Besides, food prices consistently have a significant weight in the optimal inflation target.

B.3 Extension: Fiscal Policy Interventions

In principle, fiscal transfers can help improve risk-sharing among households in the absence of complete markets. While fully state-contingent fiscal transfers

Table B.3: Welfare Comparisons under Different Levels of Food Tax or Subsidy

Scenario	*Welfare Gain*		*Weights in the Optimal Price Index*		
	Headline	*Optimal*	*Food Prices*	*Sticky Prices*	*Import Prices*
Baseline	0.16%	0.20%	0.35	0.65	0.00
5% Food Tax	0.09%	0.14%	0.30	0.70	0.00
10% Food Tax	0.04%	0.10%	0.26	0.74	0.00
5% Food Subsidy	0.25%	0.29%	0.42	0.58	0.00
10% Food Subsidy	0.37%	0.42%	0.50	0.50	0.00

Notes: The optimal price index comprises food prices, sticky nonfood domestic goods prices, and import prices. Welfare gains under different parameter values are derived as permanent consumption gains relative to strict core inflation targeting.

would be difficult for governments in emerging market economies to implement, a tax or subsidy on food is feasible.

Consider a food tax, whose revenues are distributed across all households in a lump sum fashion. This tax would lead to a larger redistribution from food sector households to other households when the economy is hit by a shock that drives up the price of food. This would result in a smaller change in the relative price of food compared to my baseline model. I conducted some numerical experiments showing that, as the food tax increased (up to a certain level), the economy approached the complete markets benchmark, with smaller gains from headline inflation targeting relative to core inflation targeting.

I get the symmetric result that food price subsidies can increase relative price volatility and improve the benefits from headline rather than core inflation targeting. The reason is that these subsidies would result in a net transfer from nonfood sector households to food sector households exactly when the relative price of food rises. These results are summarized in Table B.3.

APPENDIX C

APPENDIX TO CHAPTER 3

This appendix lists the complete system of equations that characterizes the competitive equilibrium under the baseline model, which consists of 28 endogenous variables $\{c_t^T, c_t^N, c_t, b_t^*, w_{T,t}, w_{N,t}, L_t^T, L_t^N, Y_t, Y_{N,t}, Y_{H,t}, G_t, F_t, \nu_t, R_t, \pi_t, x_{T,t}, x_{N,t}, x_{F,t}, x_{H,t}, x_t, q_t^e, e_t, \pi_{N,t}, A_{H,t}, A_{N,t}, S_t, R_t^*\}$ and 28 equations.

C.1 Household Decisions

Tradable goods sector households' budget constraints:

$$C_t^T + q_t^e b_t^* + \frac{\psi_b}{2} b_t^{*2} = R_{t-1}^* q_t^e b_{t-1}^* + w_{T,t} L_t^T \tag{C.1}$$

Nontradable goods sector households' budget constraints:

$$(1-\lambda) C_t^N = x_{N,t} Y_{N,t} \tag{C.2}$$

Tradable goods sector households' intertemporal Euler equation from domestic bonds holding:

$$C_t^{T-\sigma} = \beta E_t \left(\frac{R_t}{\pi_{t+1}} C_{t+1}^{T\ -\sigma} \right) \tag{C.3}$$

Tradable goods sector households' intertemporal Euler equation from foreign bonds holding:

$$C_t^{T^{-\sigma}} = \beta E_t \left(\frac{R_t^*}{(1 + \psi_b b_t^*)} \frac{q_{t+1}^e}{q_t^e} C_{t+1}^{T^{-\sigma}} \right) \tag{C.4}$$

Tradable goods sector households' optimal labor supply decision:

$$w_{T,t} = \phi_T C_t^{T^{\sigma}} L_t^{T^{\psi}} \tag{C.5}$$

Nontradable goods sector households' optimal labor supply decision:

$$w_{N,t} = \phi_N C_t^{N^{\sigma}} L_t^{N^{\psi}} \tag{C.6}$$

C.2 Firm Production

Cost minimization for firms in the tradable goods sector:

$$w_{T,t} = x_{H,t} A_{H,t} \tag{C.7}$$

Output in the tradable goods sector is given by:

$$Y_{H,t} = \lambda A_{H,t} L_t^T \tag{C.8}$$

Optimal price-setting in the sticky price sector is given by:

$$\left(\frac{1 - \theta \pi_{N,t}^{\varepsilon - 1}}{1 - \theta} \right)^{\frac{1}{1-\varepsilon}} = \frac{G_t}{F_t} \tag{C.9}$$

The recursive formulation of the numerator G_t:

$$G_t = \frac{\varepsilon}{\varepsilon - 1} C_t^{N-\sigma} Y_{N,t} \frac{w_{N,t}}{A_{N,t}} + \beta \theta E_t \pi_{N,t+1}^{\varepsilon} G_{t+1} \tag{C.10}$$

The recursive formulation of the denominator F_t:

$$F_t = x_{n,t} C_t^{N-\sigma} Y_{N,t} + \beta \theta E_t \pi_{N,t+1}^{\varepsilon - 1} F_{t+1} \tag{C.11}$$

The dynamics of price dispersion is given by:

$$\nu_t = (1 - \theta) \left(\frac{1 - \theta {\pi_{N,t}}^{\varepsilon - 1}}{1 - \theta} \right)^{\frac{\varepsilon}{\varepsilon - 1}} + \theta {\pi_{N,t}}^{\varepsilon} \nu_{t-1} \tag{C.12}$$

Output in the nontradable goods sector is:

$$\nu_t Y_{N,t} = (1 - \lambda) A_{N,t} L_t^N \tag{C.13}$$

C.3 Aggregate Economy

The definition of aggregate consumption is given by:

$$C_t = \lambda C_t^T + (1-\lambda)C_t^N \tag{C.14}$$

The definition of aggregate output is given by:

$$Y_t = x_{H,t}Y_{H,t} + x_{N,t}Y_{N,t} \tag{C.15}$$

The market clearing condition for nontradable goods is given by:

$$(1-b)x_{N,t}^{-\xi}C_t = Y_{N,t} \tag{C.16}$$

C.4 Price, Inflation and Monetary Policy

Nontradable goods price index and relative prices:

$$x_{N,t} = x_{N,t-1}\frac{\pi_{N,t}}{\pi_t} \tag{C.17}$$

Home-produced tradable goods price dynamics:

$$x_{H,t} = x_{H,t-1} \frac{q_t^e}{q_{t-1}^e} \frac{s_t}{s_{t-1}} \tag{C.18}$$

Foreign-produced tradable goods price dynamics:

$$x_{F,t} = x_{F,t-1} \frac{q_t^e}{q_{t-1}^e} \tag{C.19}$$

Price index in the Tradable goods sector is given by:

$$x_{T,t} = x_{F,t} \left[a s_t^{1-\eta} + (1-a) \right]^{\frac{1}{1-\eta}} \tag{C.20}$$

Aggregate price index and relative prices:

$$1 = \left[b x_{T,t}^{1-\xi} + (1-b) x_{N,t}^{1-\xi} \right]^{\frac{1}{1-\xi}} \tag{C.21}$$

The definition of the relative price:

$$x_t = \frac{x_{N,t}}{x_{H,t}} \tag{C.22}$$

The definition of the real exchange rate:

$$\frac{q_t^e}{q_{t-1}^e} = \frac{e_t}{e_{t-1} \pi_t} \tag{C.23}$$

Monetary policy rule (baseline model):

$$log\left(\frac{R_t}{\bar{R}}\right) = \rho\ log\left(\frac{R_{t-1}}{\bar{R}}\right) + (1-\rho)\left[\phi_\pi log\left(\frac{\pi_t}{\bar{\pi}}\right) + \phi_e log\left(\frac{e_t}{e_{t-1}}\right)\right] \tag{C.24}$$

C.5 Shocks

Productivity shock in the tradable goods sector:

$$log\left(\frac{A_{H,t}}{\overline{A}_H}\right) = \rho_a^H log\left(\frac{A_{H,t-1}}{\overline{A}_H}\right) + \varepsilon_t^H \tag{C.25}$$

Productivity shock in the nontradable goods sector:

$$log\left(\frac{A_{N,t}}{\overline{A}_N}\right) = \rho_a^N log\left(\frac{A_{N,t-1}}{\overline{A}_N}\right) + \varepsilon_t^N \tag{C.26}$$

Terms of trade shock in the tradable goods sector:

$$log\left(\frac{S_t}{\overline{S}}\right) = \rho_s log\left(\frac{S_{t-1}}{\overline{S}}\right) + \varepsilon_t^\sigma \tag{C.27}$$

Foreign interest shock:

$$log\left(\frac{R_t^*}{\overline{R}^*}\right) = \rho_r log\left(\frac{R_{t-1}^*}{\overline{R}^*}\right) + \varepsilon_t^r \tag{C.28}$$

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